Spawning Escapement Update for the Lake Washington Watershed

Washington Department of FISH and WILDLIFE

Seattle Public Utilities

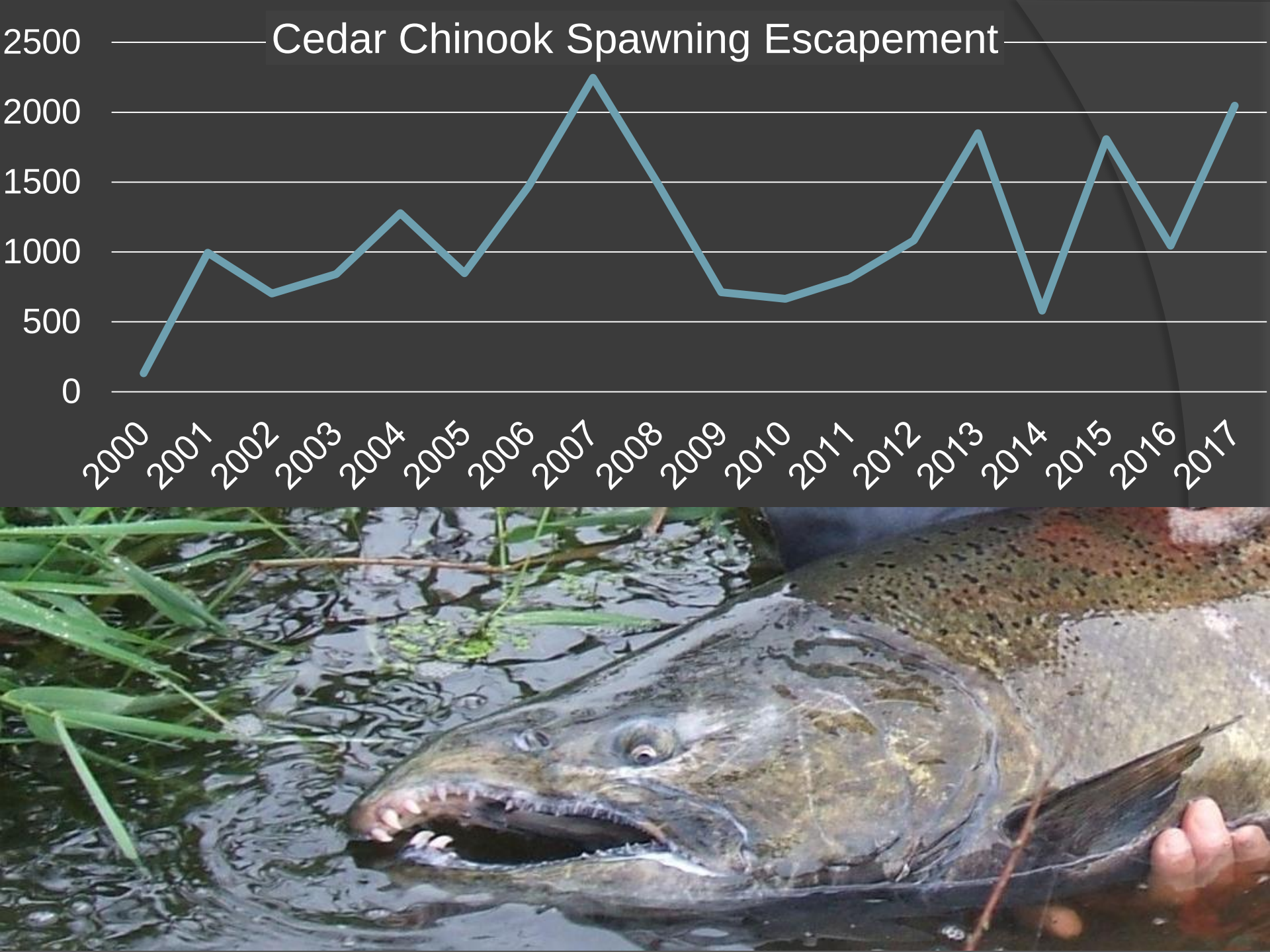
King County

City of Bellevue

Muckleshoot Indian Tribe

WDFW

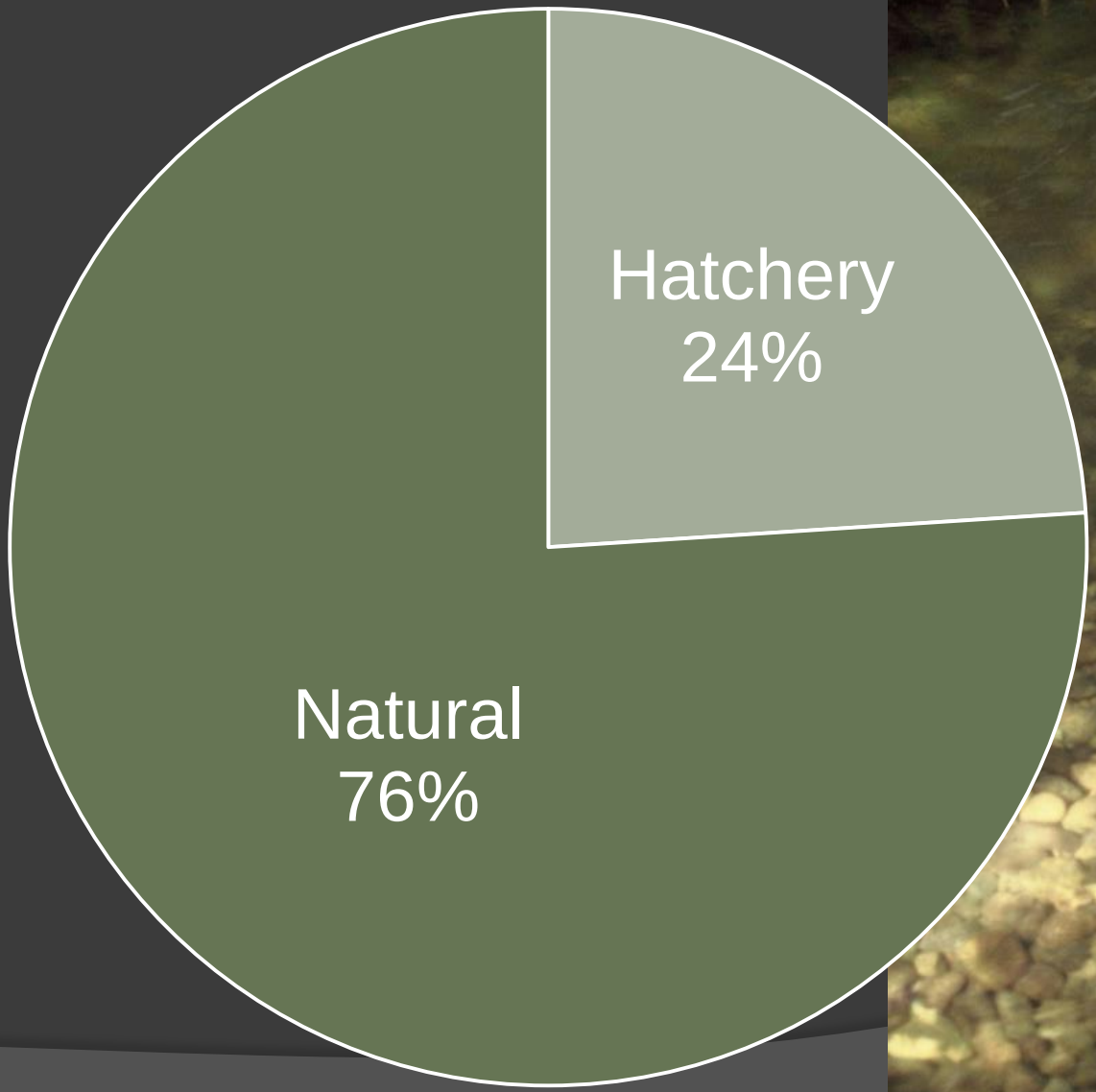

2017 Cedar Chinook Spawning
Escapement: 2,048 Fish

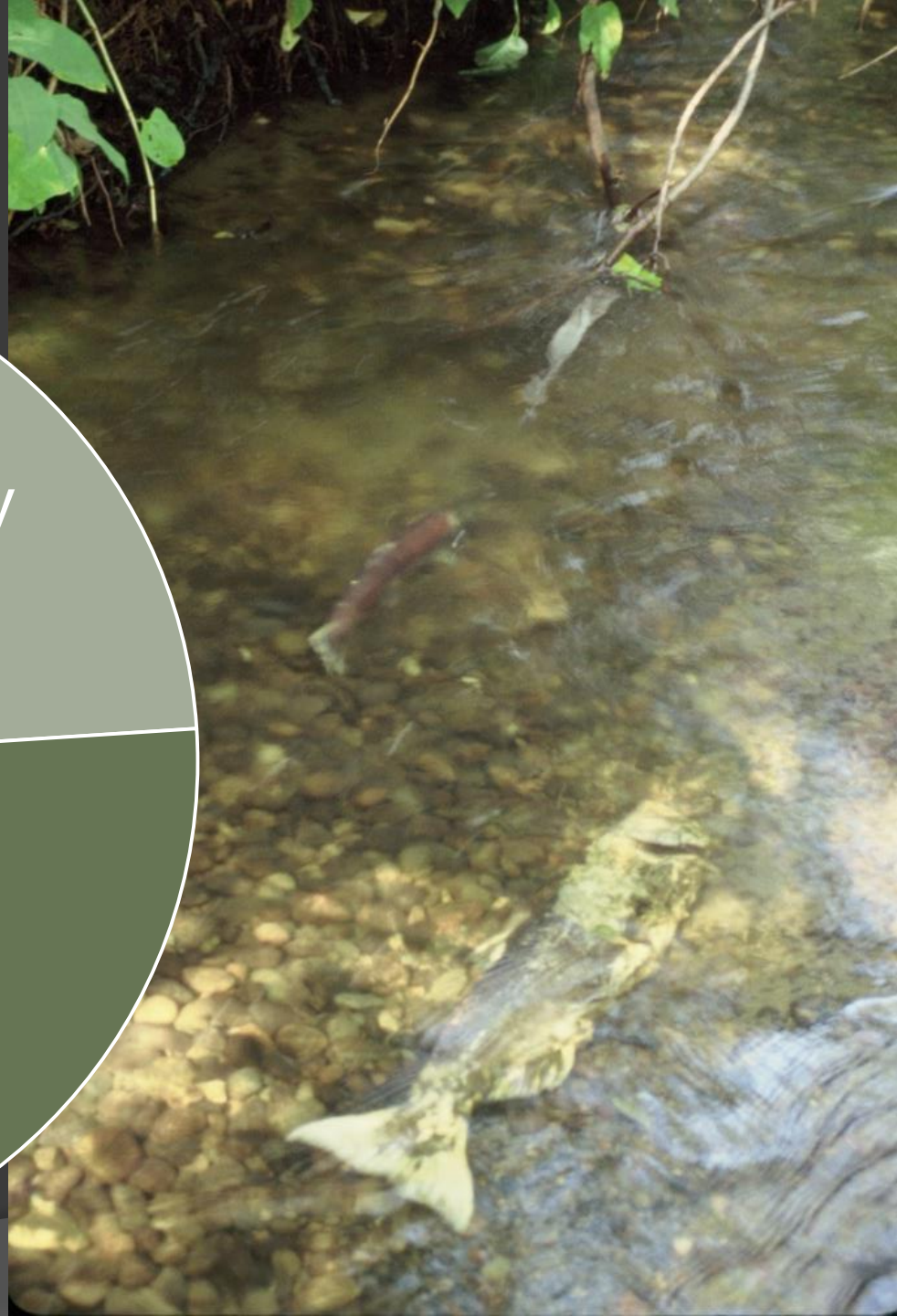

Cedar Chinook Spawning Escapement
2500
2000
1500
1000
500
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

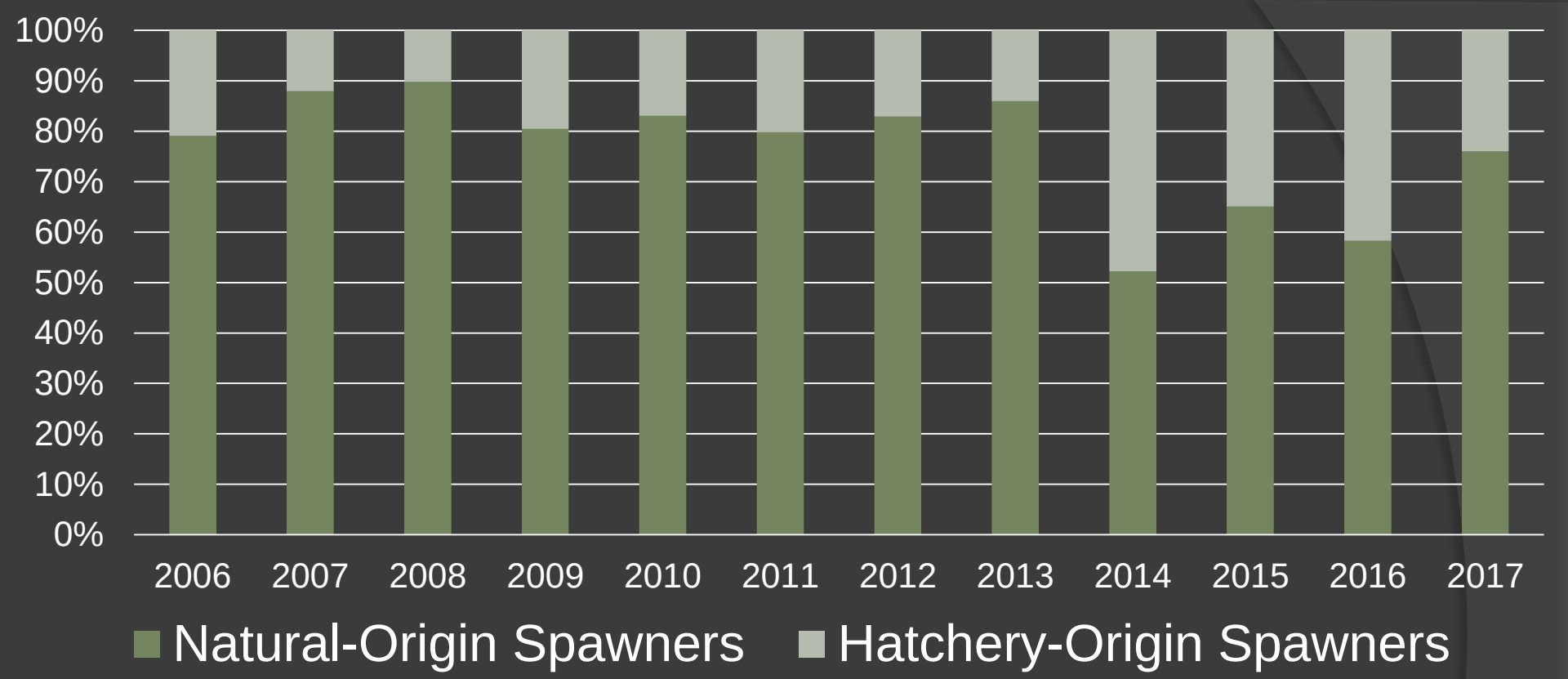
Estimating Chinook Spawning Escapement: Boat Surveys and Complete Redd Census

Carcass Survey Data

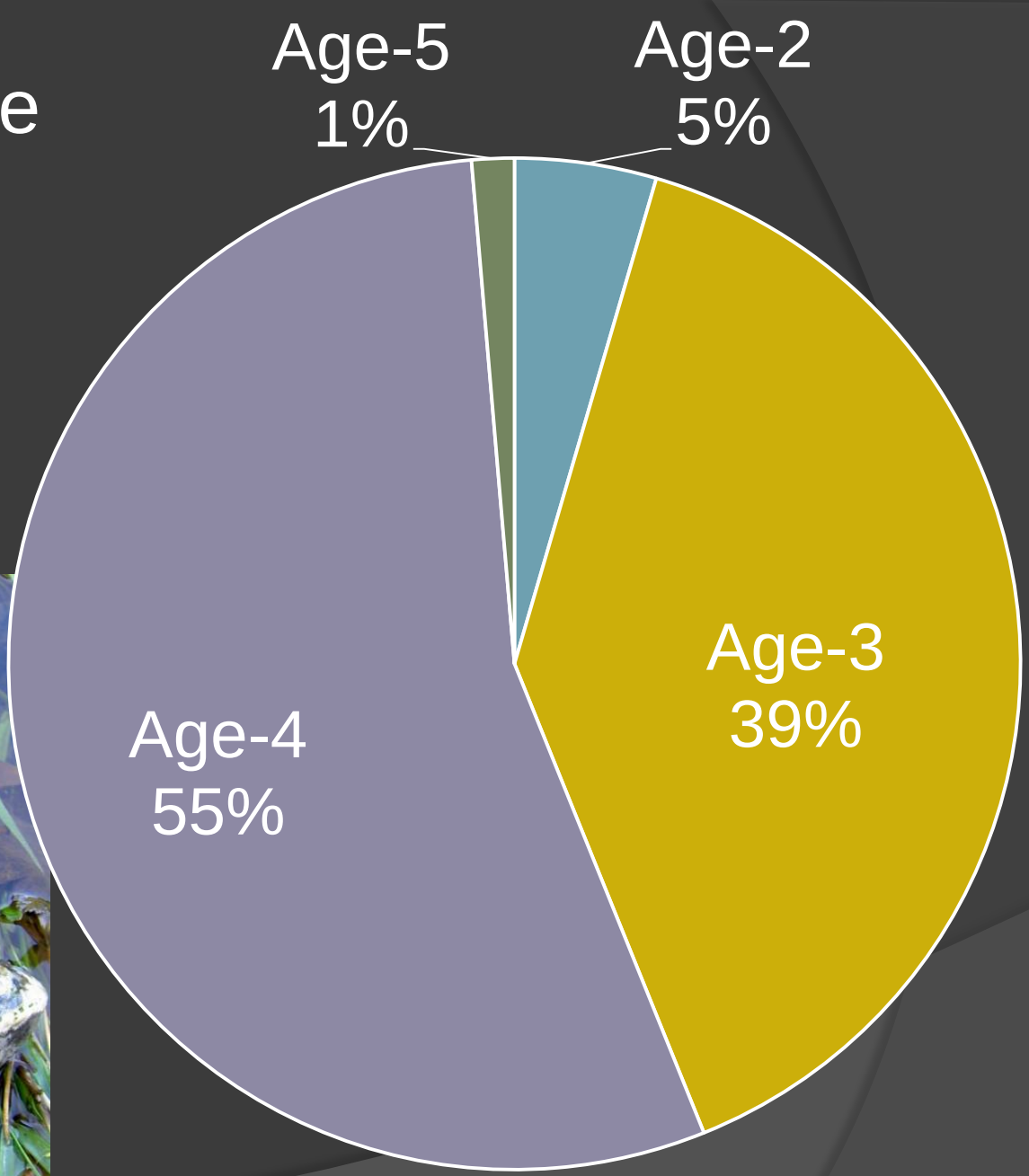
2017 Cedar Chinook

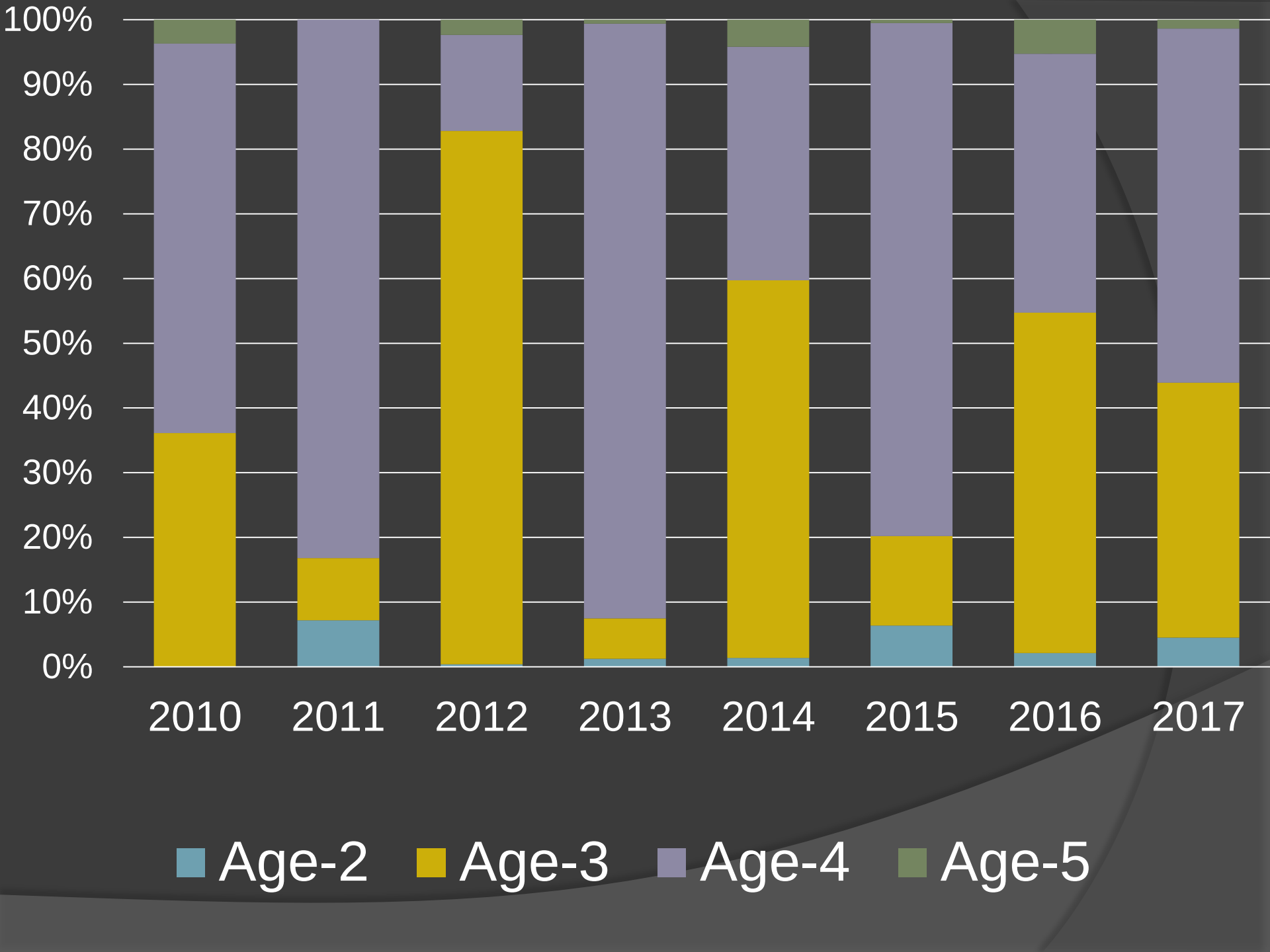





100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Natural-Origin Spawners
Hatchery-Origin Spawners

Cedar Chinook Age 2017



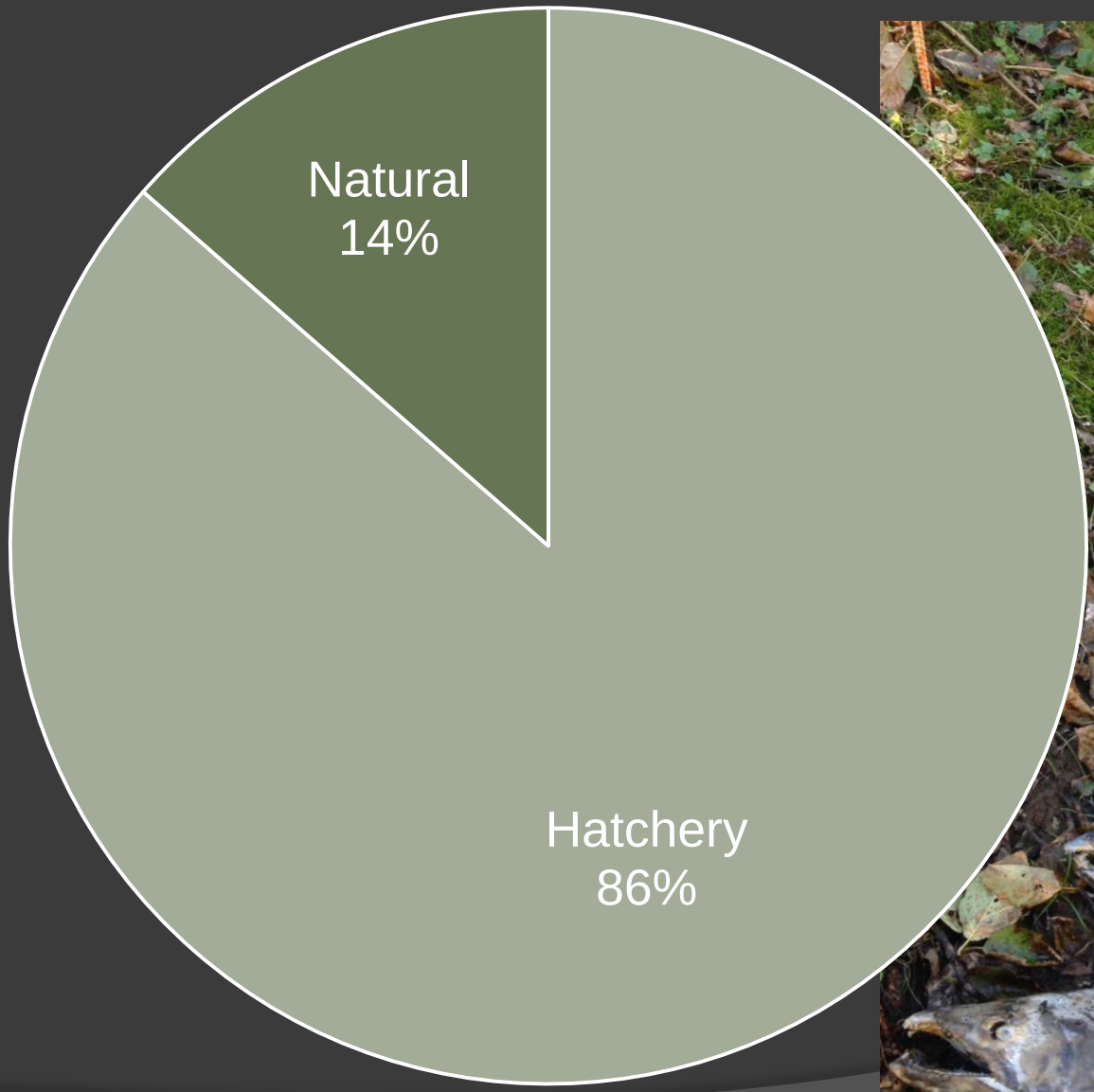

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2011
2012
2013
2014
2015
2016
2017
Age-2
Age-3
Age-4
Age-5

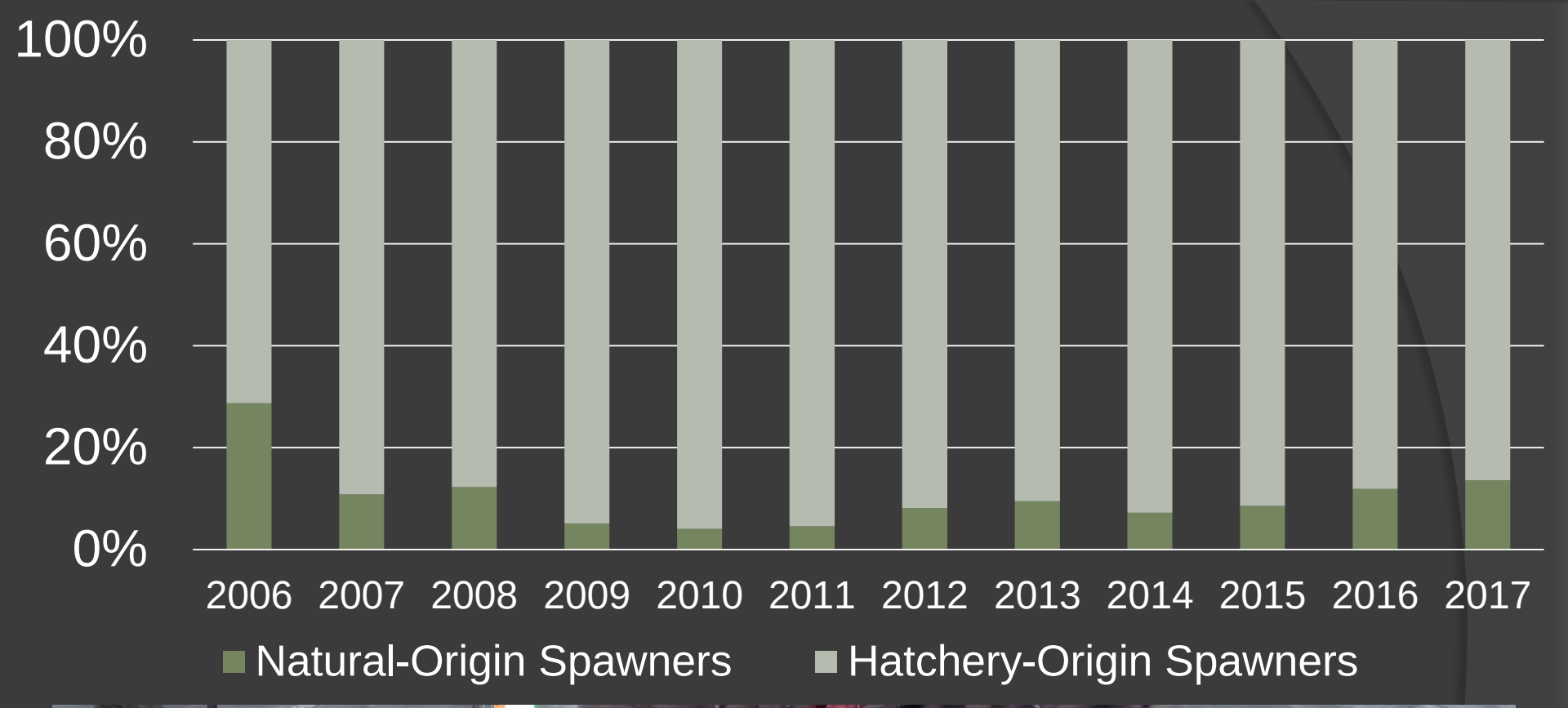

Big Bear Creek
Issaquah Hatchery
Cedar River
Monroe
Sultan
Gold Bar
Lynnwood
Edmonds
Mountlake Terrace
Bothell
Indianola
Suquamish
Kirkland
Redmond
Bainbridge Island
Seattle
Bellevue
Issaquah
North Bend
Burien
Vashon
Renton
Maple Valley
Hobart
Covington
Federal Way
Auburn
Black Diamond
Cedar River
Chester Morse Lake
UNION HILL
1822 m
99
405
520
90
18

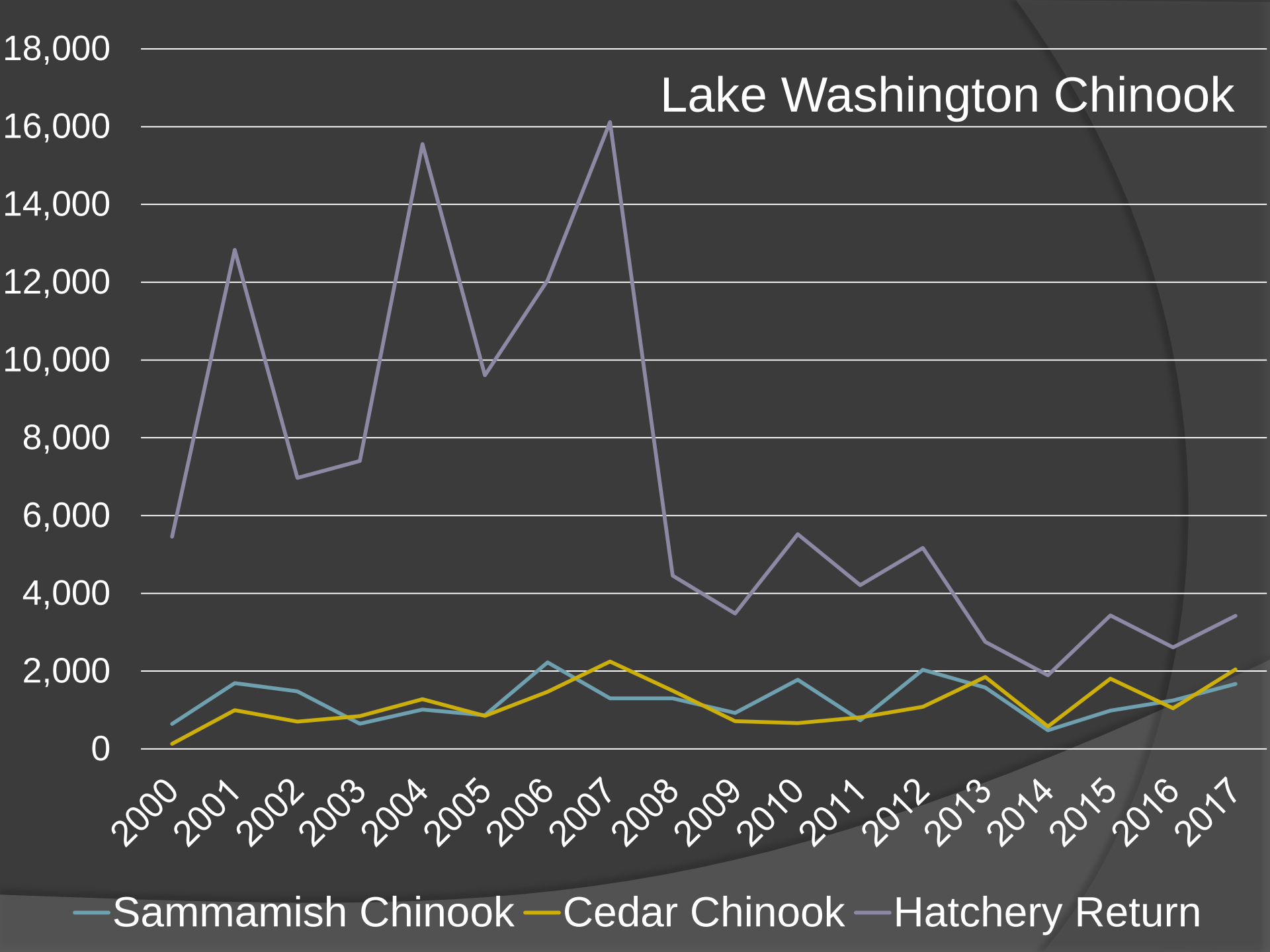

Sammamish Chinook Spawning Escapement
2,500
2,000
1,500
1,000
500
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

Foot Surveys

Sammamish Chinook 2017

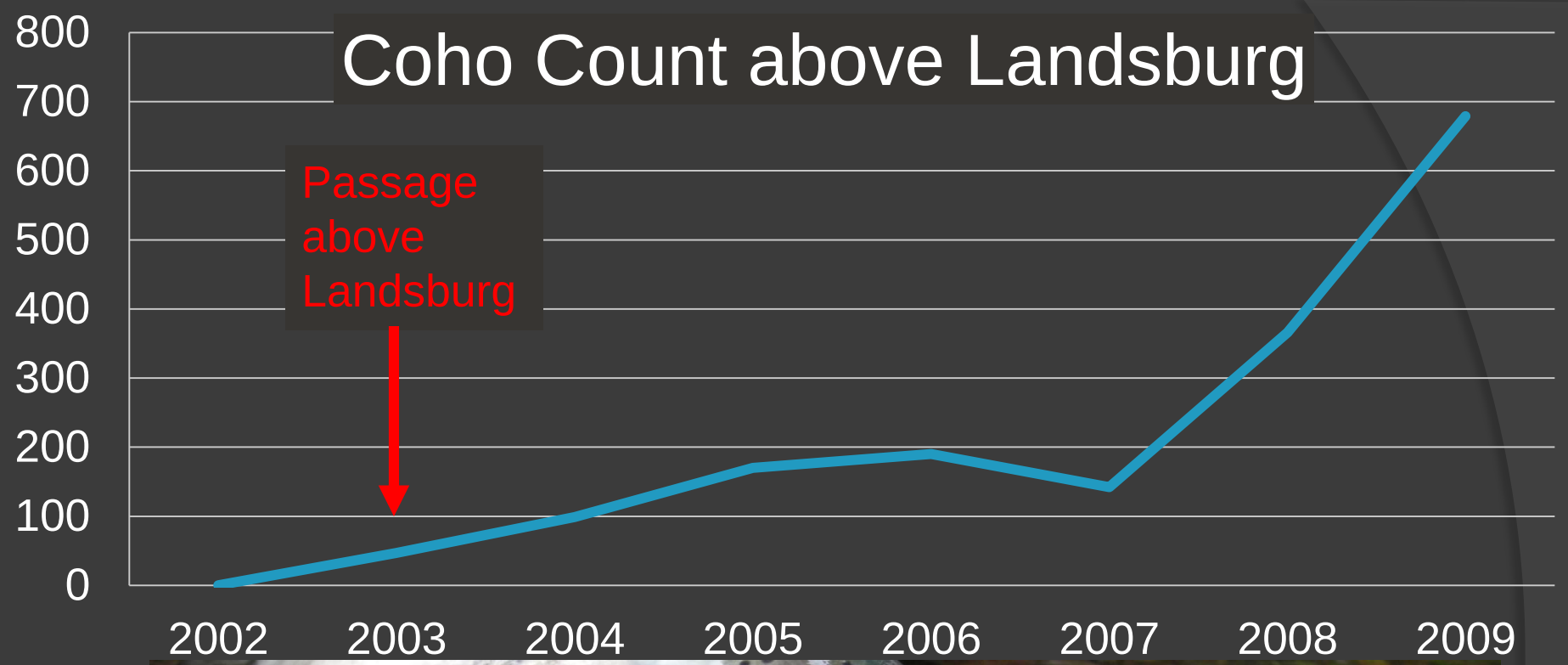



100%
80%
60%
40%
20%
0%
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Natural-Origin Spawners
Hatchery-Origin Spawners

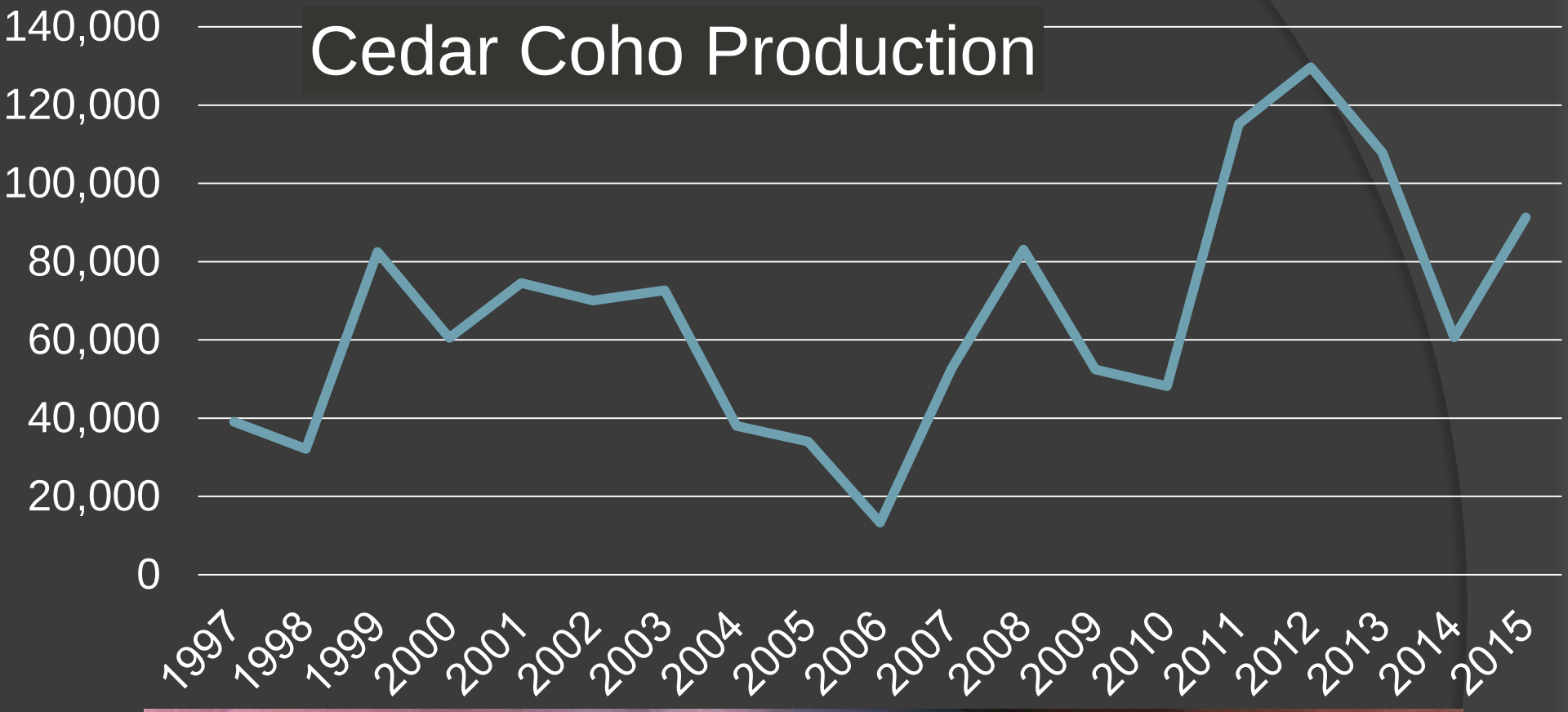

Lake Washington Chinook
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Sammamish Chinook
Cedar Chinook
Hatchery Return

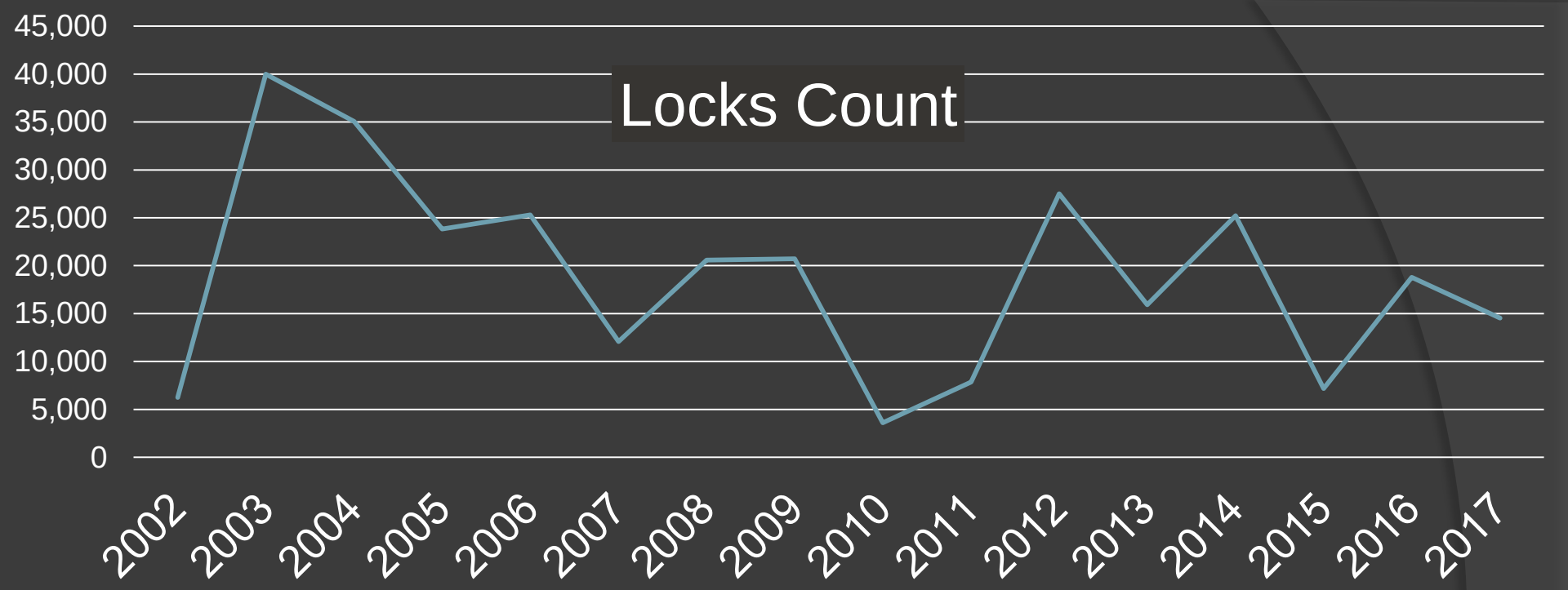
Cedar River Coho

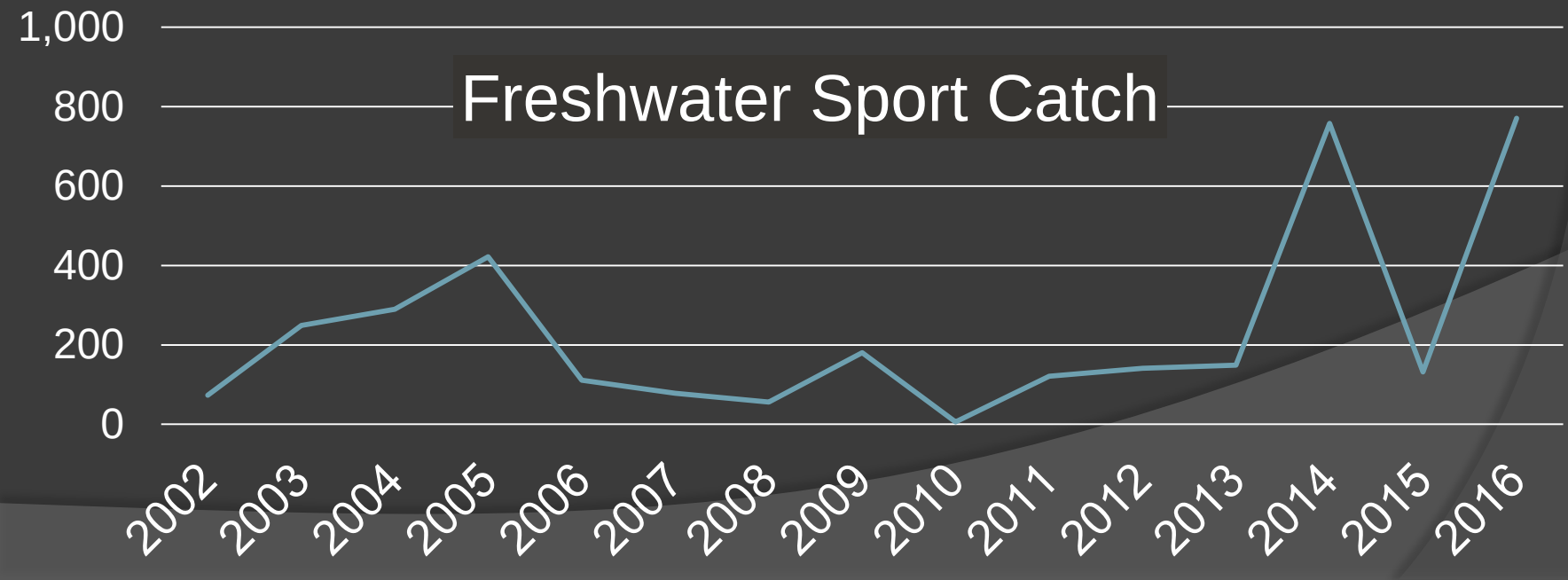
Coho Count above Landsburg



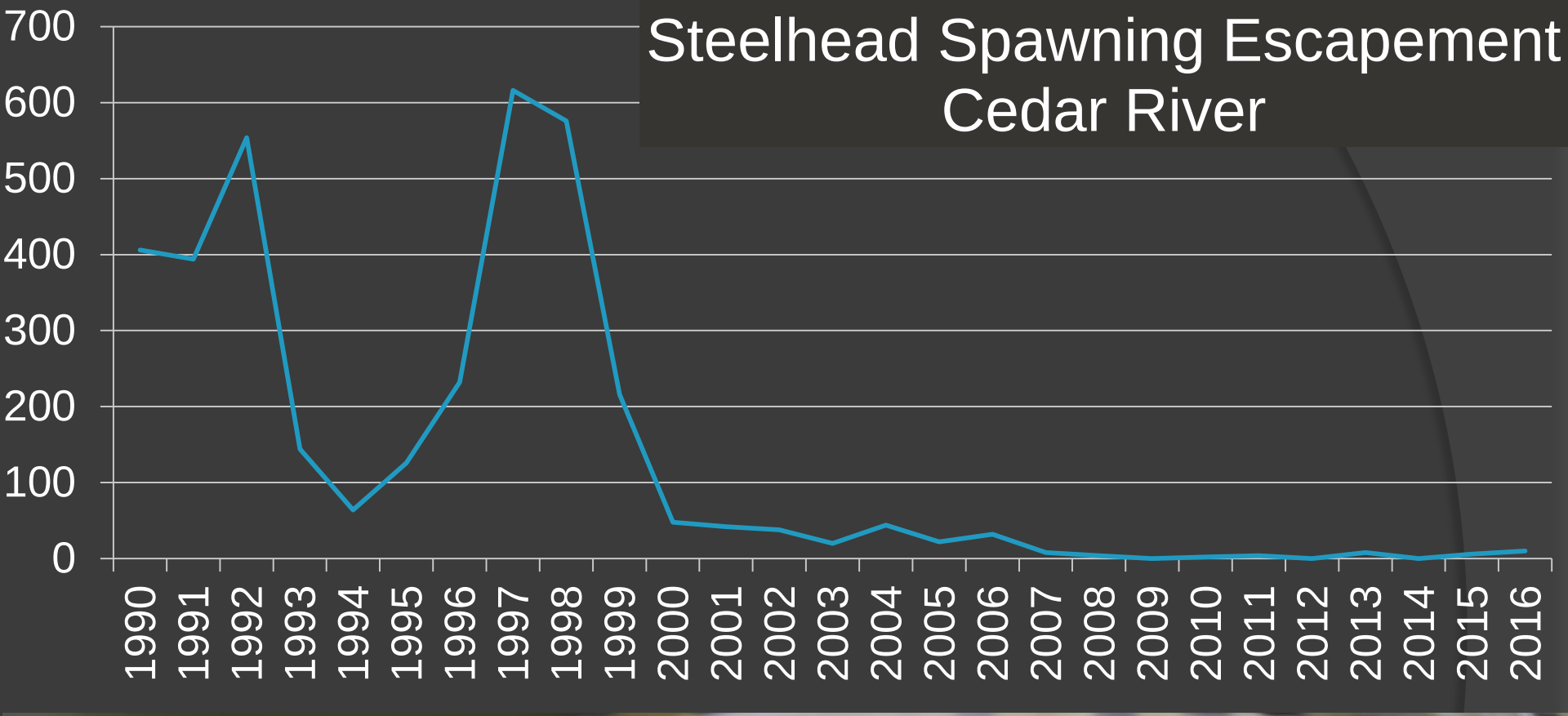
Cedar Coho Production



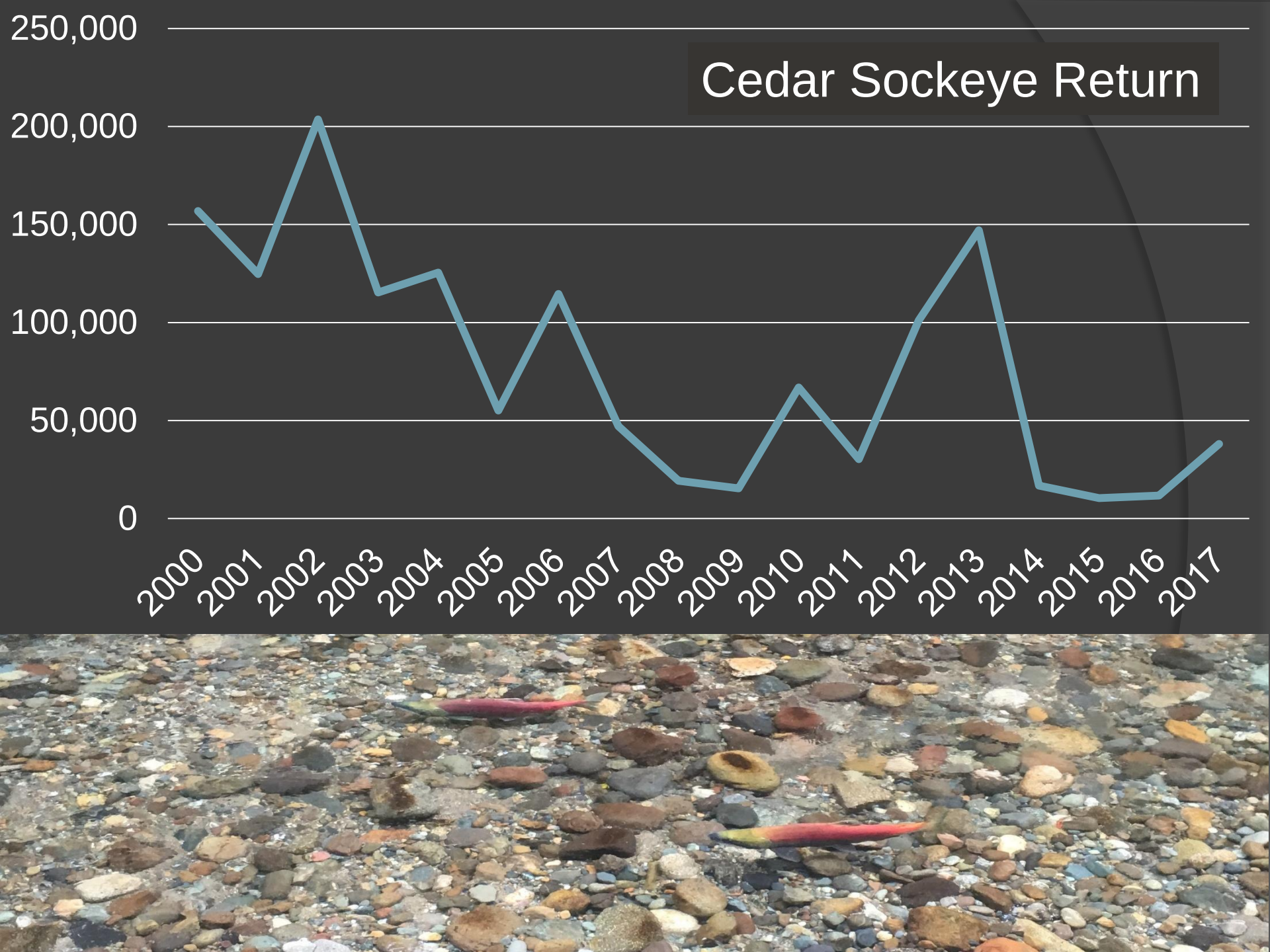

Locks Count
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


Freshwater Sport Catch
1,000
800
600
400
200
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Steelhead Spawning Escapement
Cedar River



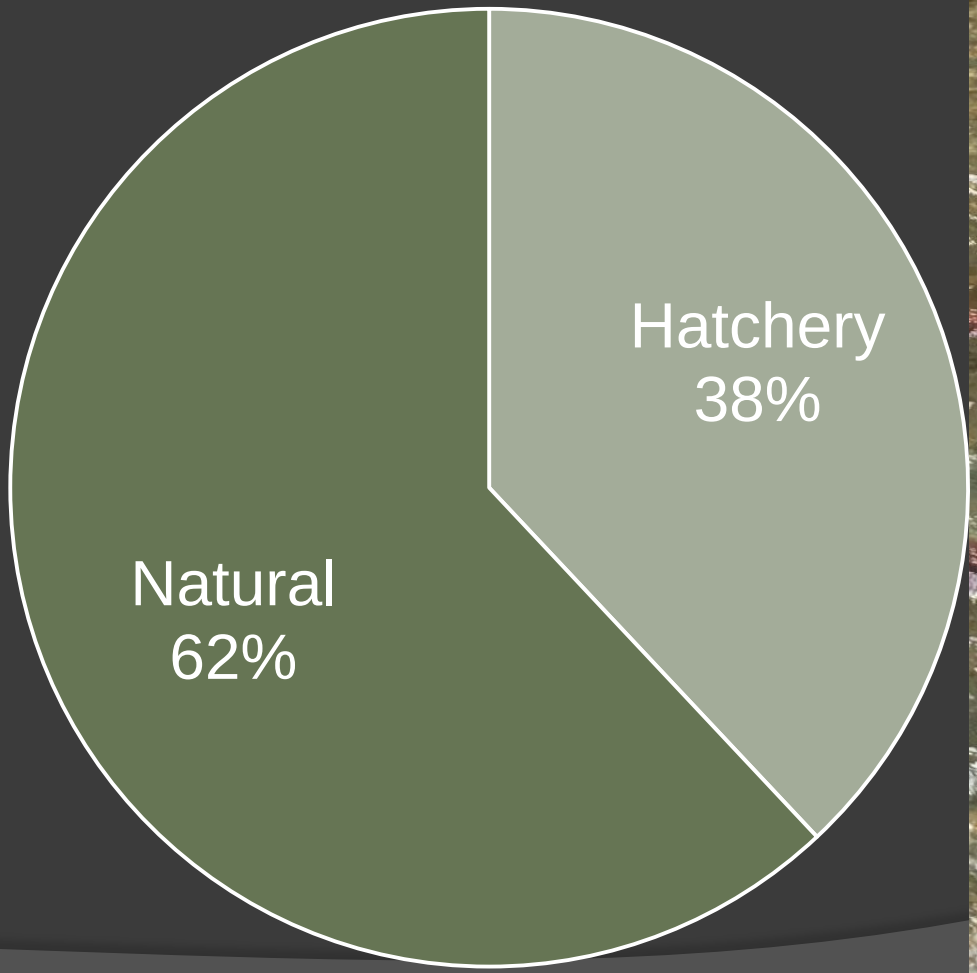

Cedar River Sockeye
2017 Cedar Sockeye
Escapement: ~38,000 Fish

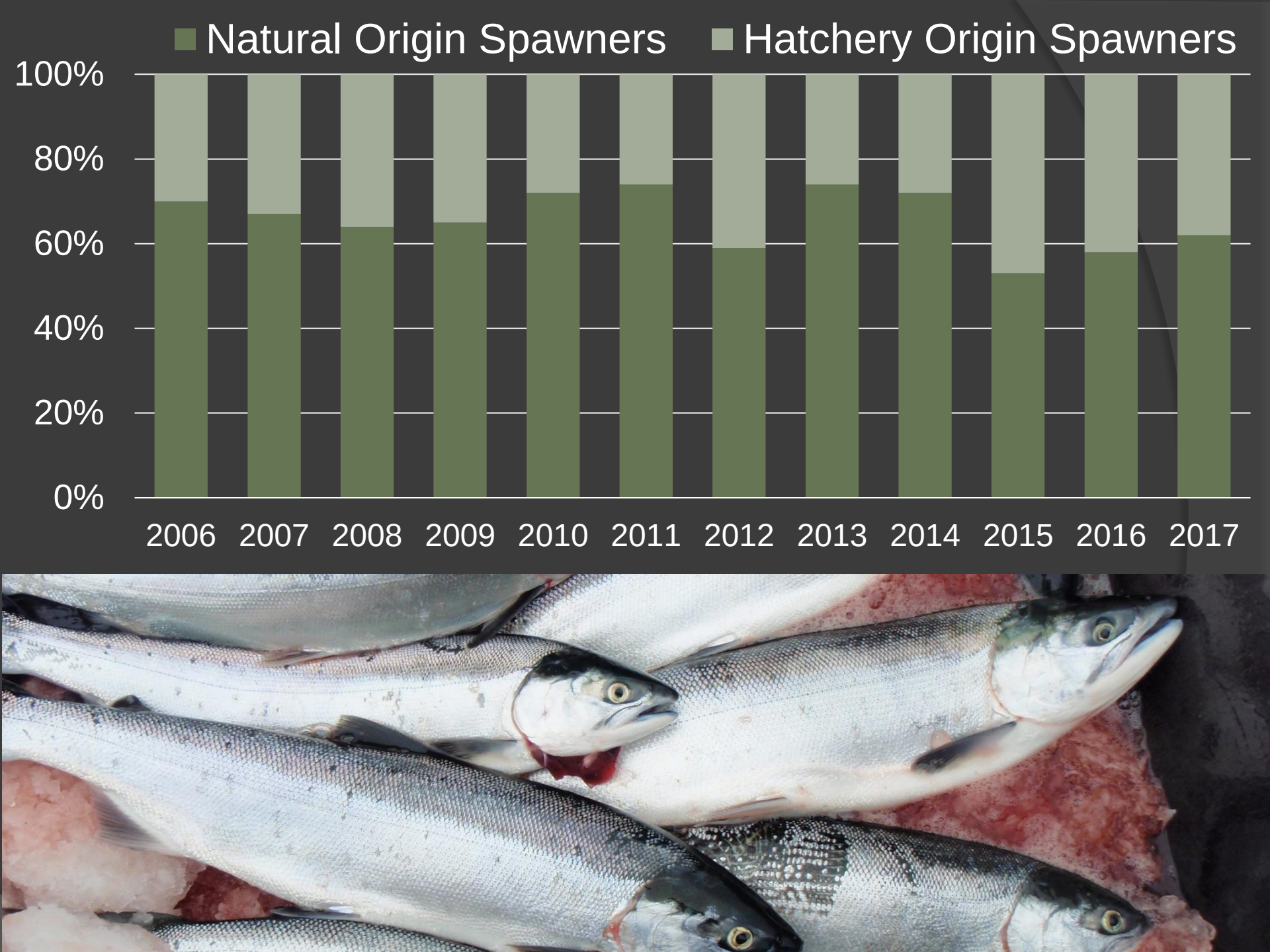

Cedar Sockeye Return
250,000
200,000
150,000
100,000
50,000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

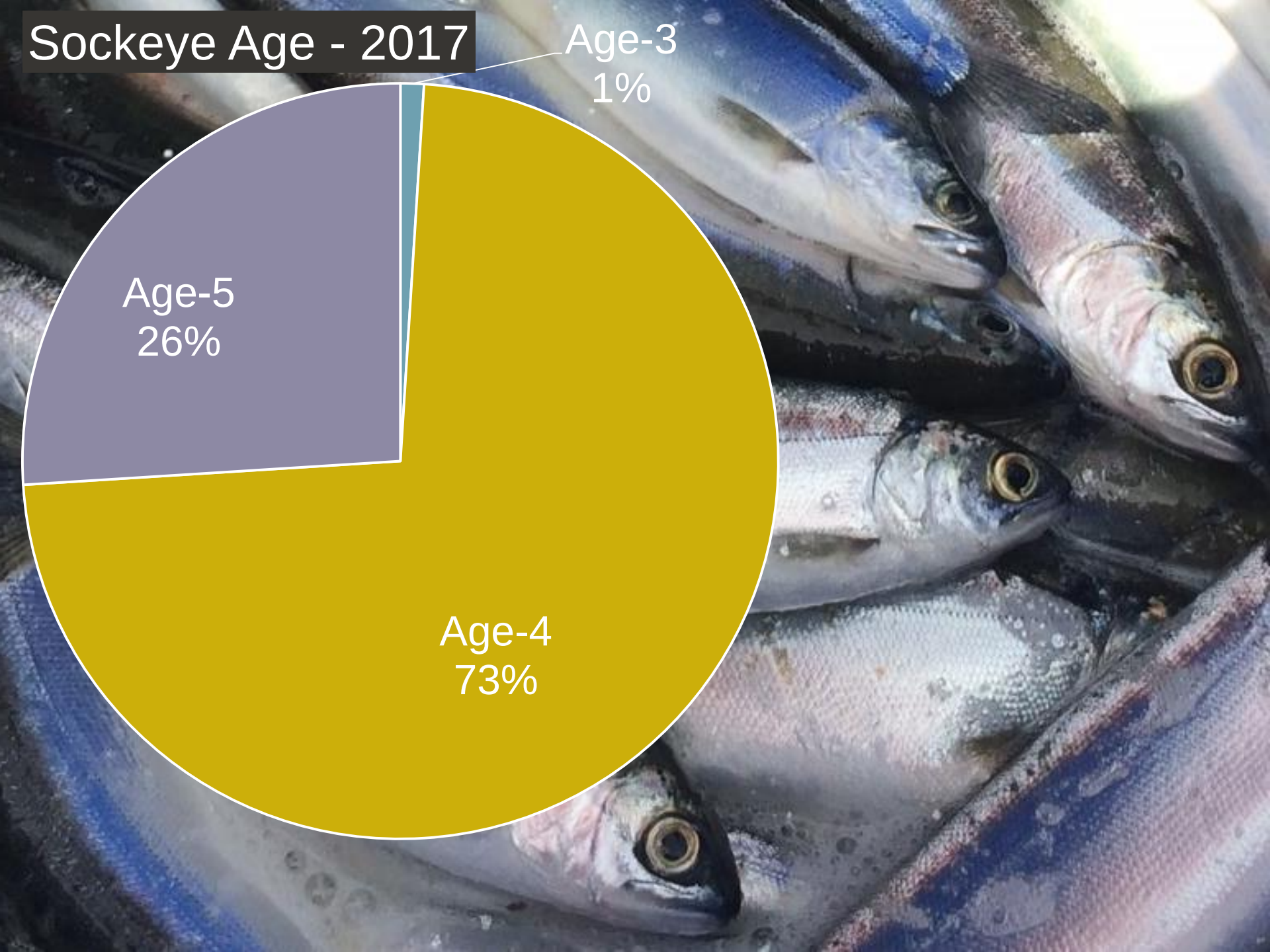
1968 Cedar River Sockeye Survey

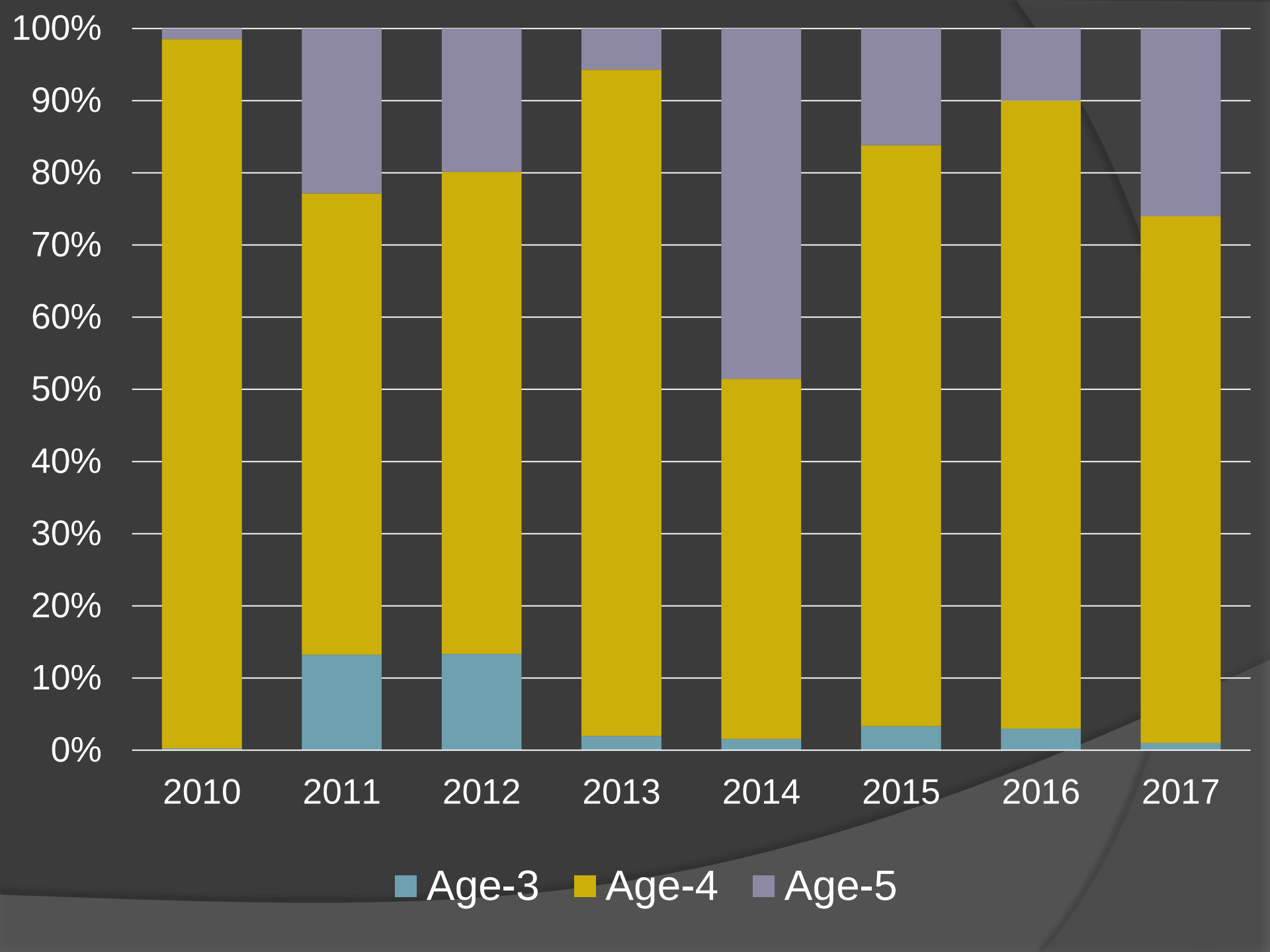
Estimating Sockeye Spawning Escapement: Boat Surveys and Live Fish Counts

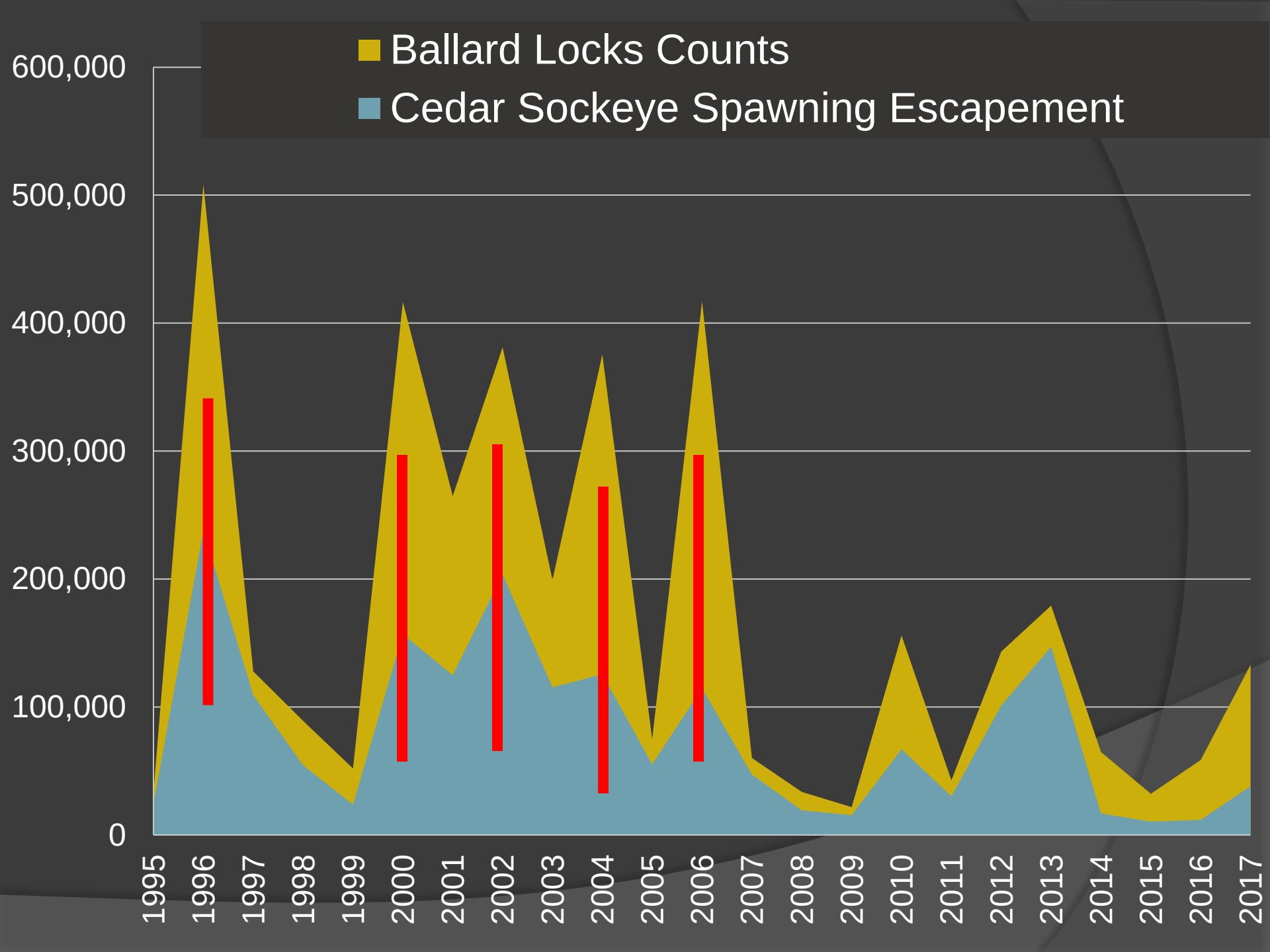
Cedar Sockeye 2017

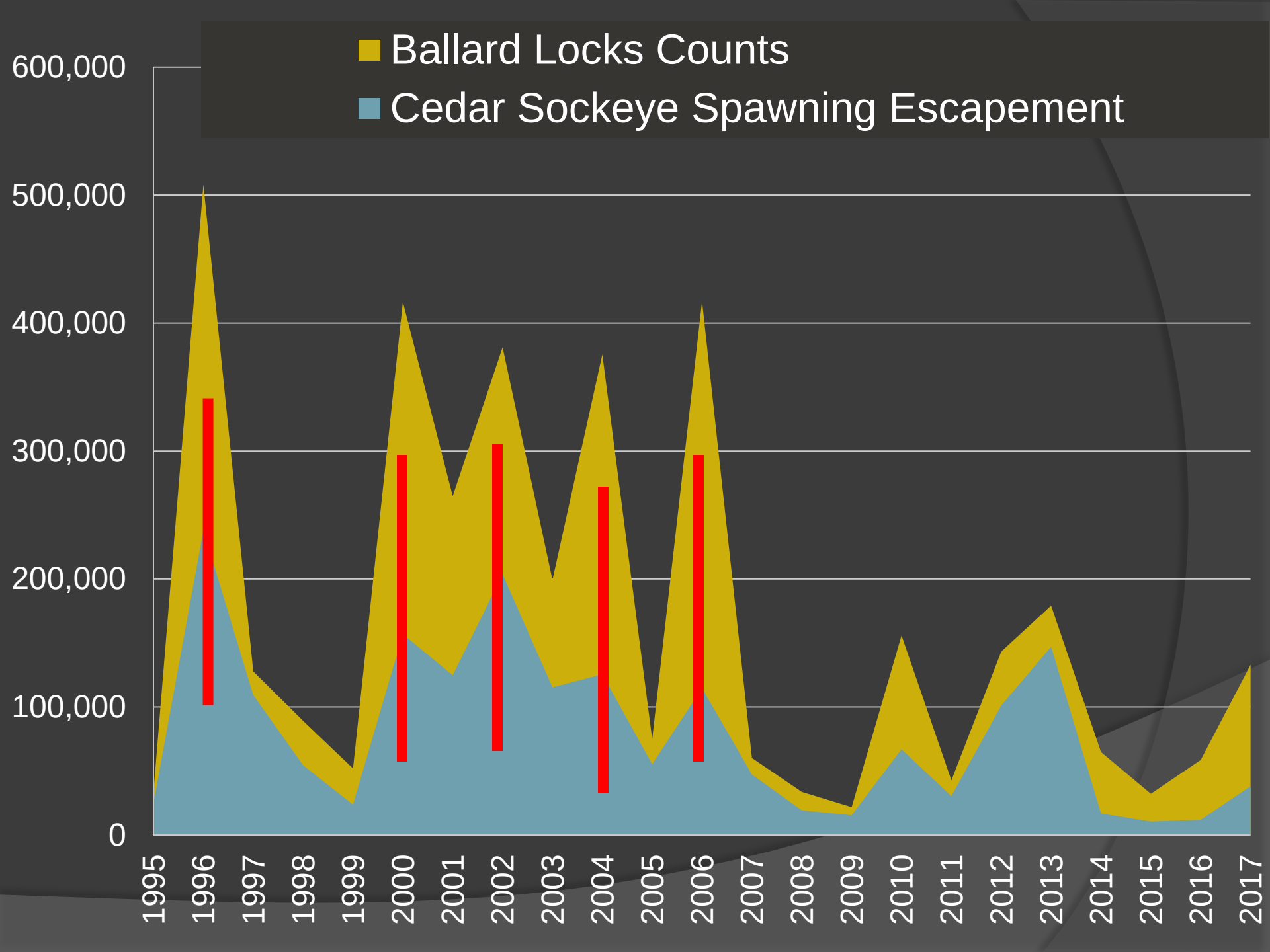



Natural Origin Spawners
Hatchery Origin Spawners
100%
80%
60%
40%
20%
0%
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


Sockeye Age - 2017
Age-3
1%
Age-5
26%
Age-4
73%


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2010
2011
2012
2013
2014
2015
2016
2017
Age-3
Age-4
Age-5


Ballard Locks Counts
Cedar Sockeye Spawning Escapement
600,000
500,000
400,000
300,000
200,000
100,000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

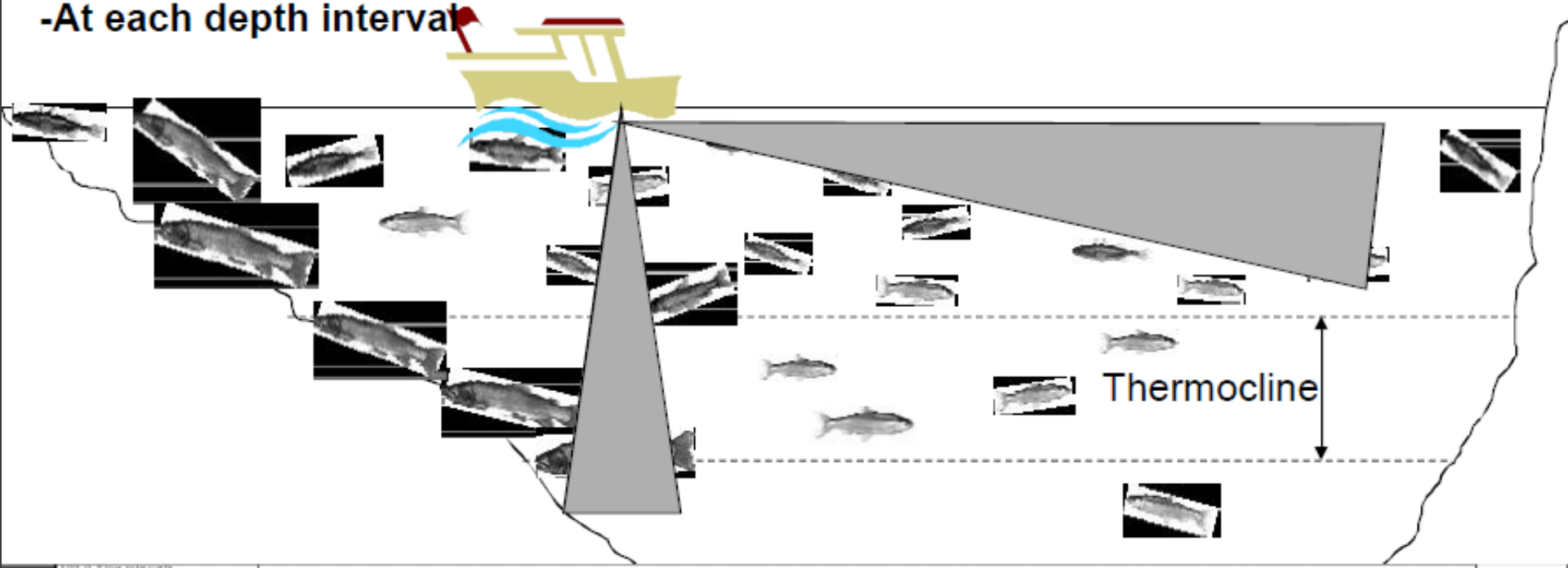

Ballard Locks Counts
Cedar Sockeye Spawning Escapement
600,000
500,000
400,000
300,000
200,000
100,000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

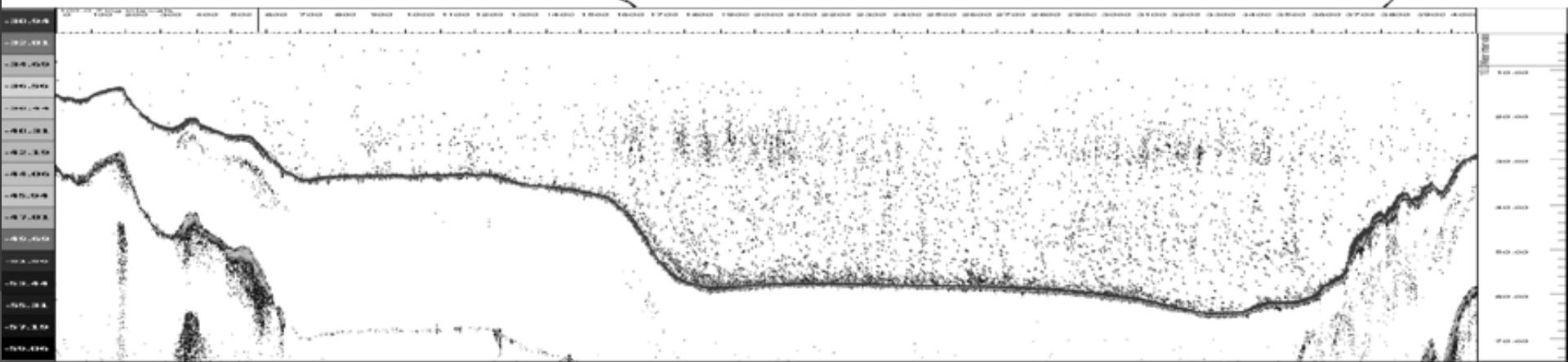
Planktivore Distribution & Abundance

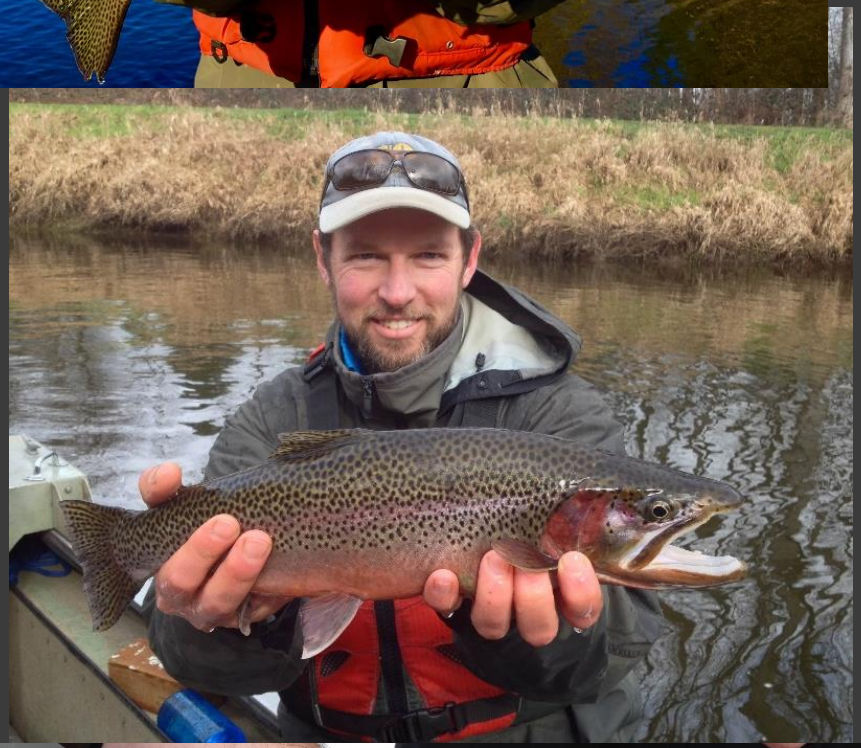
HYDROACOUSTICS (Splitbeam, multiplexed down- & side-looking)

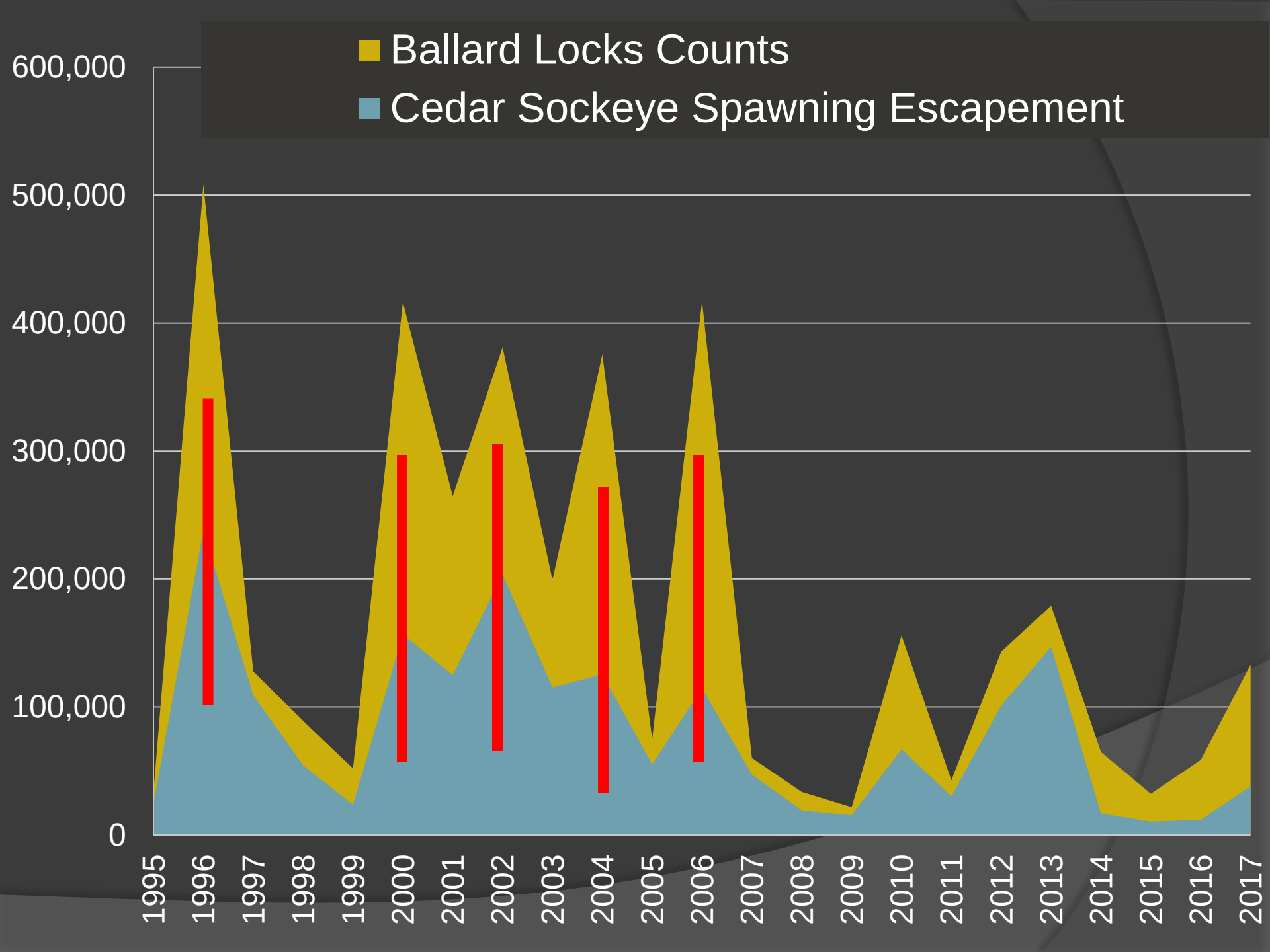
Measure fish density & abundance by:

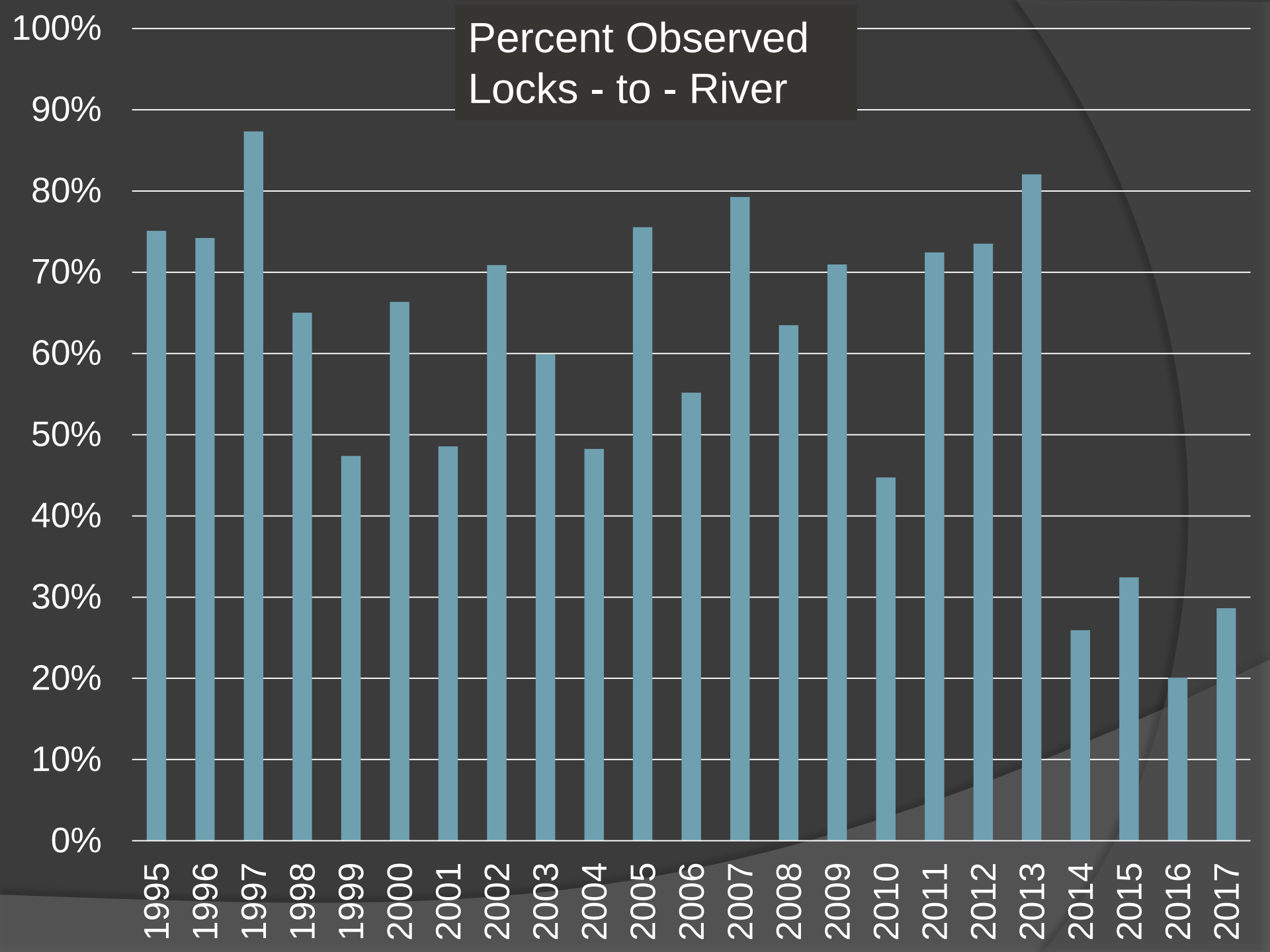
- -For different size classes of fish
- -At each depth interval








Ballard Locks Counts
Cedar Sockeye Spawning Escapement
600,000
500,000
400,000
300,000
200,000
100,000
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017


Percent Observed
Locks - to - River
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

Cedar River Sockeye Life Cycle Model

Natural eggs
Hatchery eggs

Egg-to-fry survival

Natural fry
Hatchery fry

Fry-to-pre-smolt survival

Natural pre-smolts
Hatchery pre-smolts

SAR, ocean age composition

Natural adults at Ballard locks
Hatchery adults at Ballard locks

Pre-spawn mortality from Locks to Cedar River

Natural adults to Cedar River
Hatchery adults to Cedar River

Proportion of run captured at the weir

Natural spawners
Hatchery spawners

% female, fecundity

Natural spawners
Hatchery spawners

Natural eggs
Hatchery
eggs

Egg-to-fry survival

Natural fry
Hatchery fry

Fry-to-pre-smolt survival

Natural pre-smolts
Hatchery pre-
smolts

SAR, ocean age composition

Natural adults
at Ballard locks
Hatchery
adults at
Ballard locks

Pre-spawn mortality from Locks to Cedar River

Natural adults to Cedar River
Hatchery adults to Cedar River

Proportion of run captured at the weir


DANGER
HAZARD
MOVE
NO
TRESPASSING

Natural eggs
Hatchery eggs

Natural fry
Hatchery fry

Fry-to-pre-smolt survival

Natural pre-smolts
Hatchery pre-smolts

SAR, ocean age composition

Natural adults at Ballard locks
Hatchery adults at Ballard locks

Pre-spawn mortality from Locks to Cedar River

Natural adults to Cedar River
Hatchery adults to Cedar River

Proportion of run captured at the weir

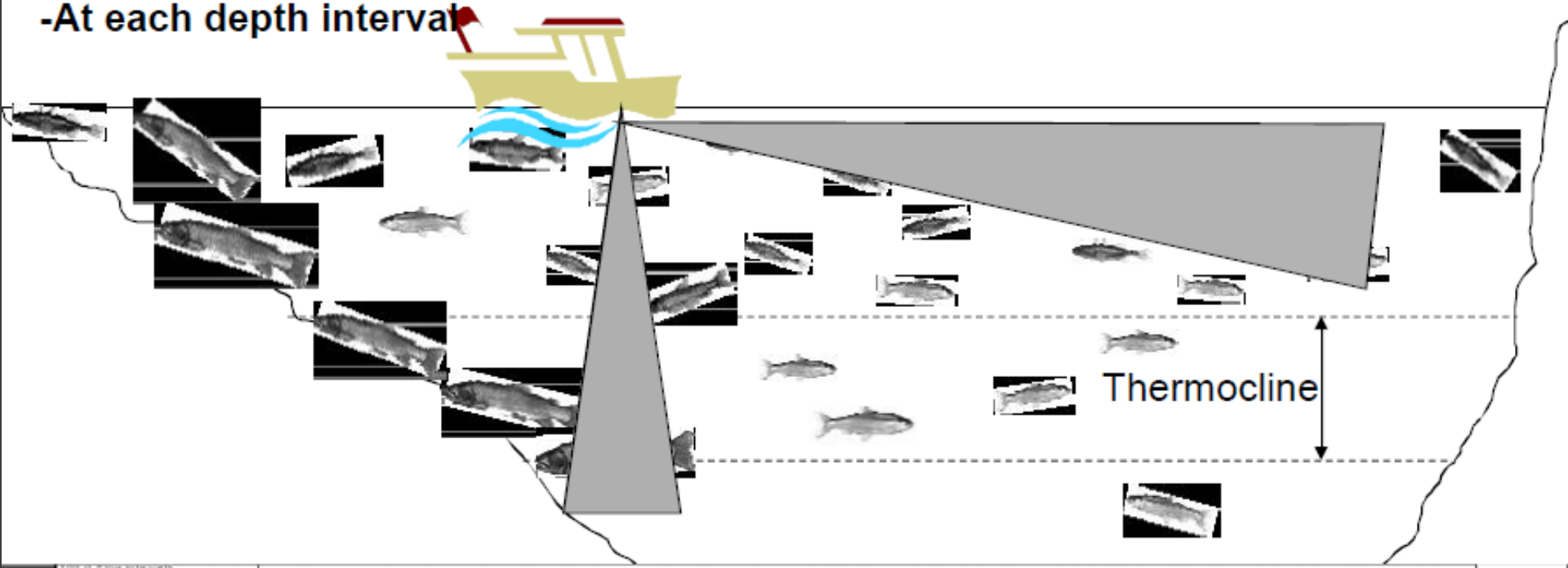
Natural spawners
Hatchery spawners

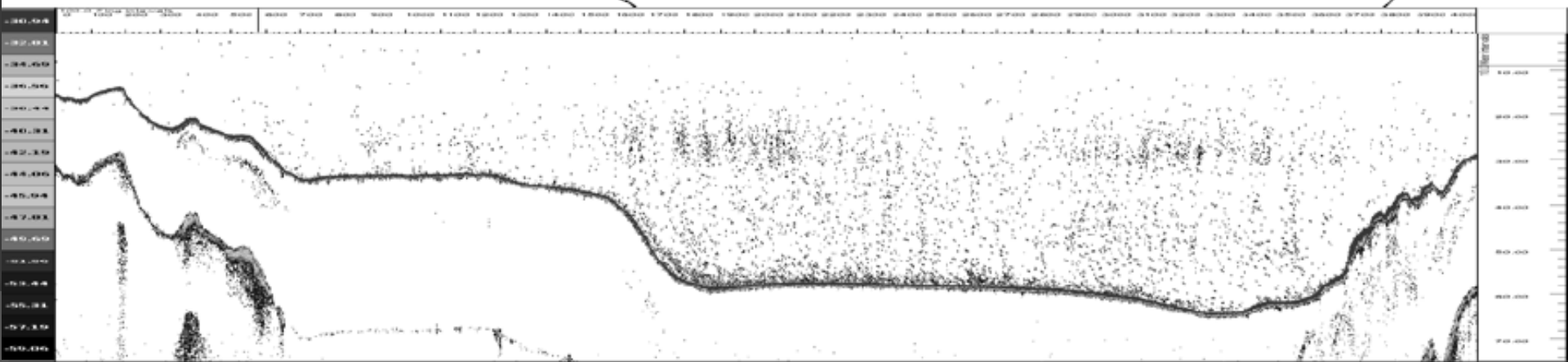
Planktivore Distribution & Abundance

HYDROACOUSTICS (Splitbeam, multiplexed down- & side-looking)

Measure fish density & abundance by:

- -For different size classes of fish
- -At each depth interval



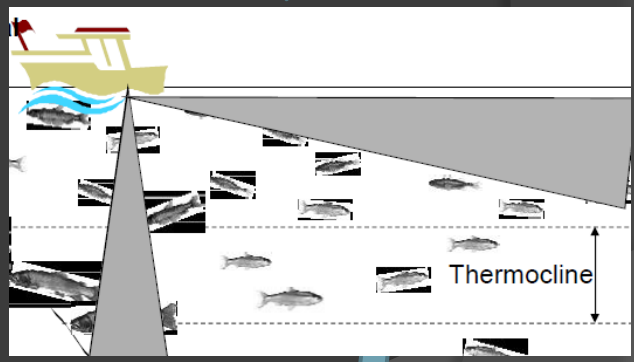


Natural spawners
Hatchery spawners

Natural eggs
Hatchery
eggs

Natural fry
Hatchery fry

Fry-to-
pre-smolt
survival



Natural adults
at Ballard locks
Hatchery
adults at
Ballard locks

SAR, ocean age
composition

Pre-spawn mortality from
Locks to Cedar River

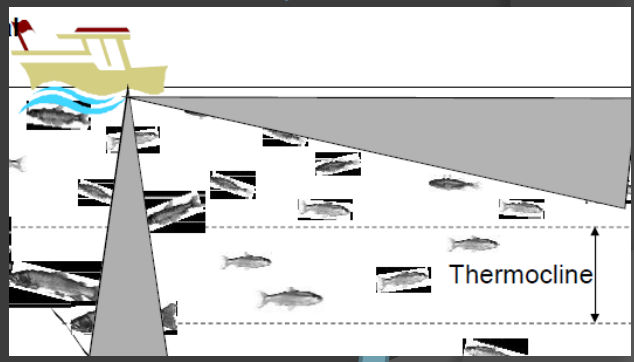
Natural adults to Cedar River
Hatchery adults to Cedar River

Proportion
of run
captured at
the weir

Natural eggs
Hatchery eggs

Natural fry
Hatchery fry

Fry-to-pre-smolt survival



SAR, ocean age composition

Pre-spawn mortality from Locks to Cedar River

Natural adults to Cedar River
Hatchery adults to Cedar River

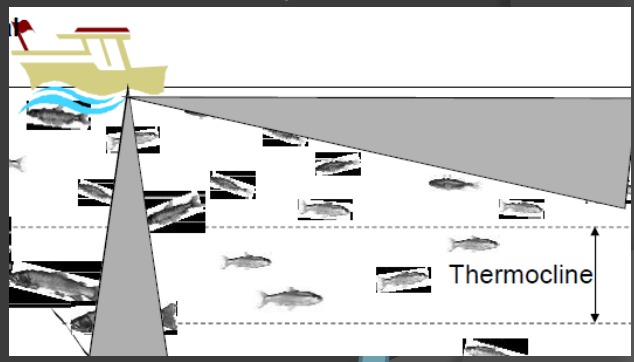
Proportion of run captured at the weir

Natural spawners
Hatchery spawners

Natural eggs
Hatchery eggs

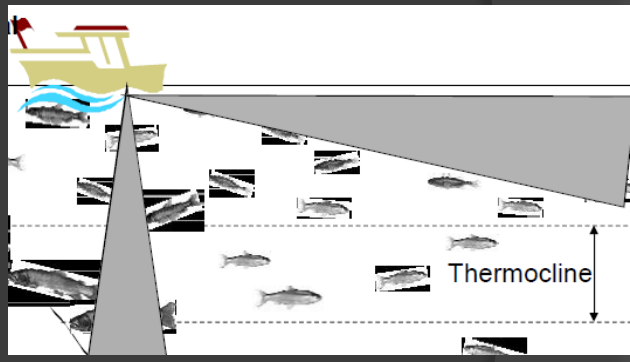
Natural fry
Hatchery fry

Fry-to-pre-smolt survival



SAR, ocean age composition

Proportion of run captured at the weir


Thermocline

Running the model

- Pick a scenario (current conditions or adjusted)
- Stochasticity (random variation) added to each stage of the model
- Run the model 100 years into the future
- Run the model 1000 times for each scenario
- Calculate and plot average of annual values across runs (black line) plus each individual run (thin grey lines)

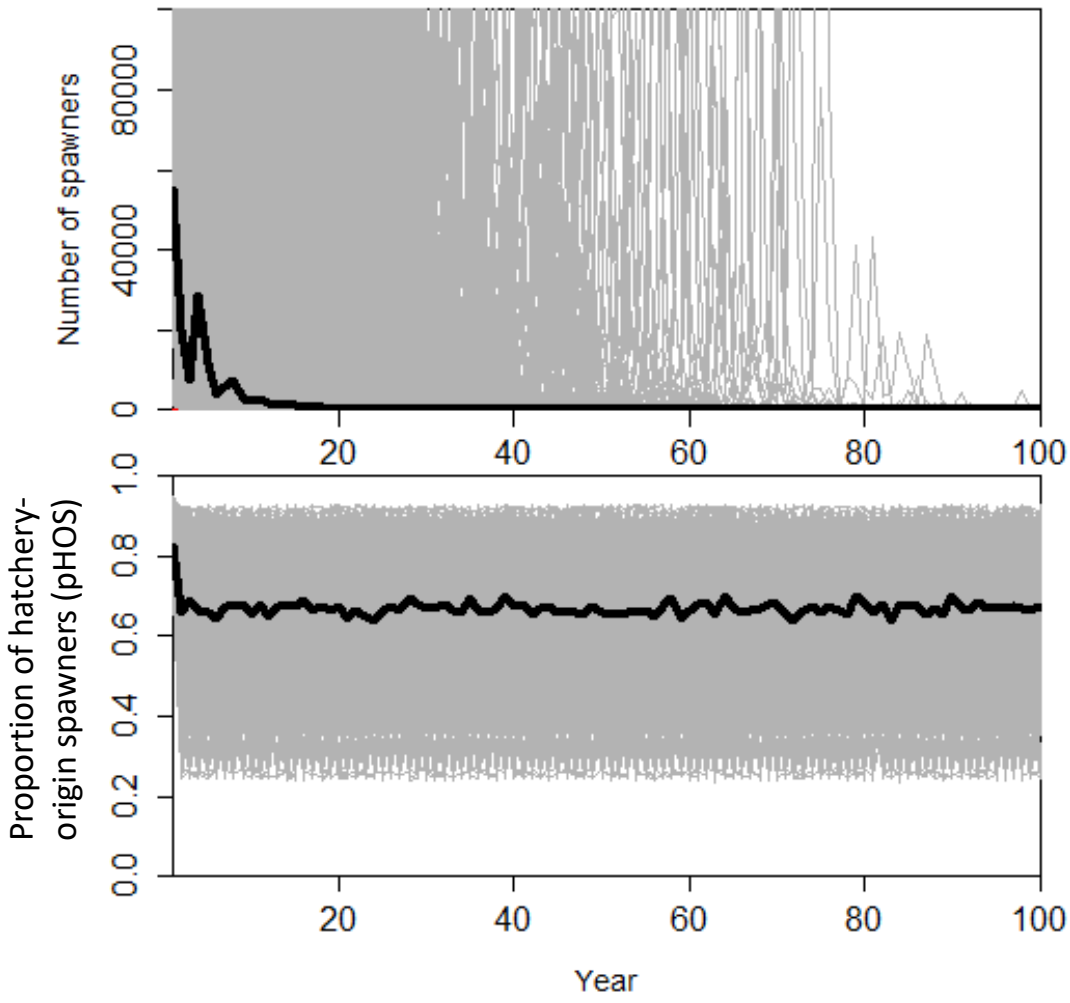
Model and data limitations

- We recognize that uncertainty exists in some of the information used in our model
- Alternative hypotheses may exist regarding the low survival rates seen in some life stages in recent years
- We will continue to review and improve the data used
- This modeling effort helps to inform the prioritization of future research and monitoring

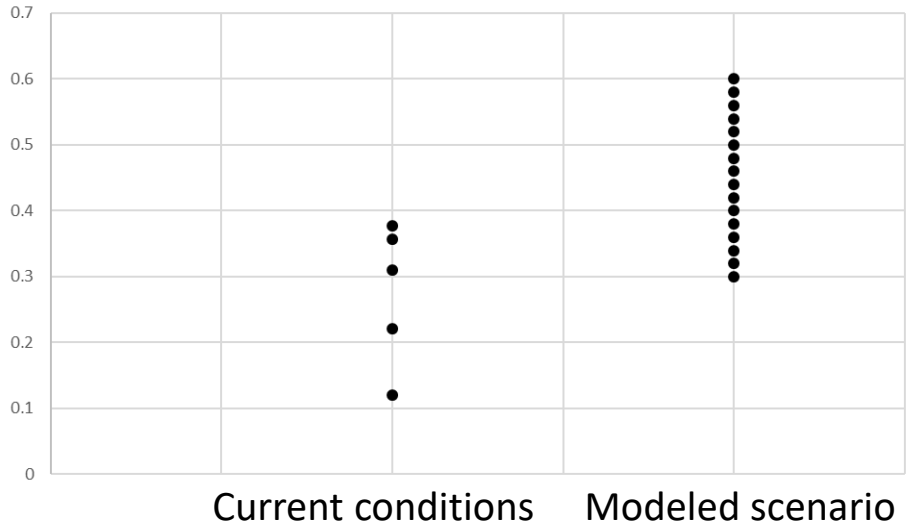
Some scenarios to model:

1. Increased proportion of run captured at weir
2. Decreased pre-spawning mortality
3. Increase fry to pre-smolt survival (to 3-4%) [current = 1-4%]
4. Increase fry to pre-smolt survival (to 4-8%) [current = 1-4%]
5. Decreased pre-spawning mortality, increased proportion of run captured at weir, and increase fry to pre-smolt survival (to 2-4%)

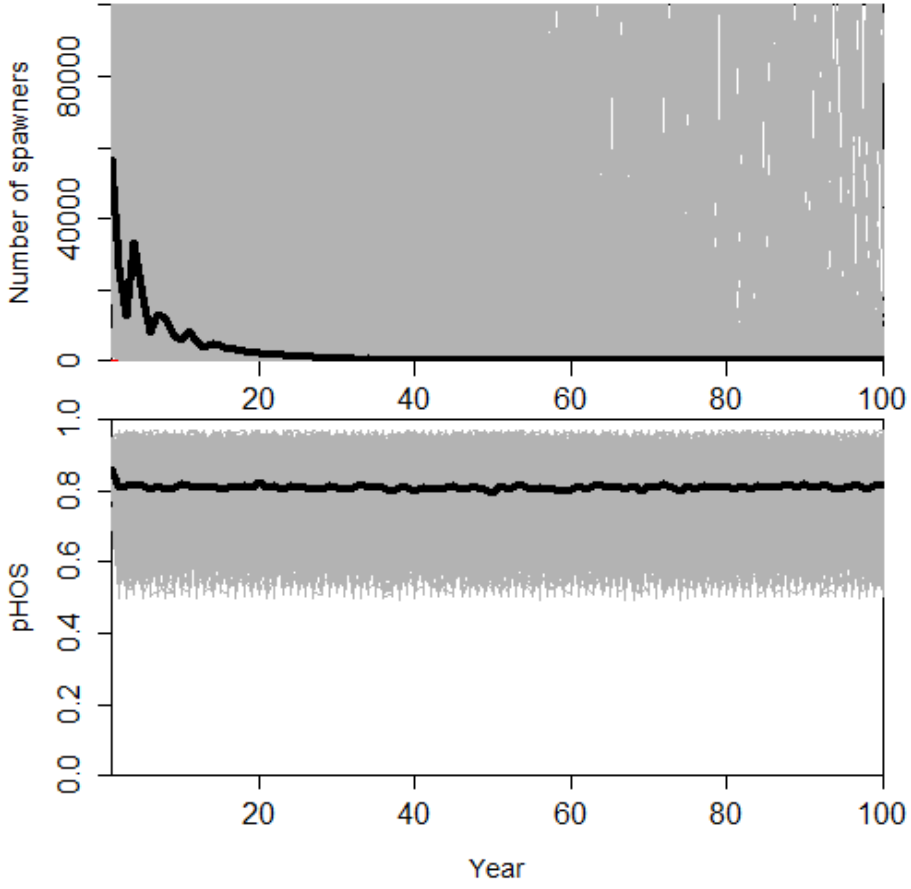
Results—current conditions



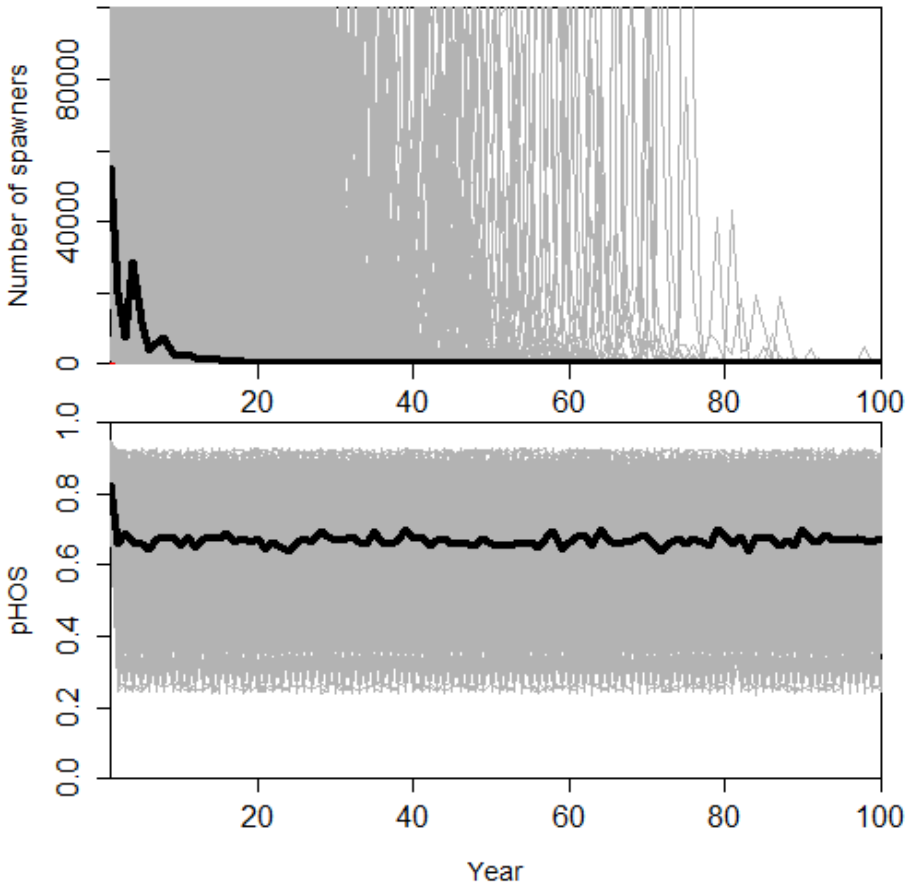
Scenario: increased proportion of run captured at the weir



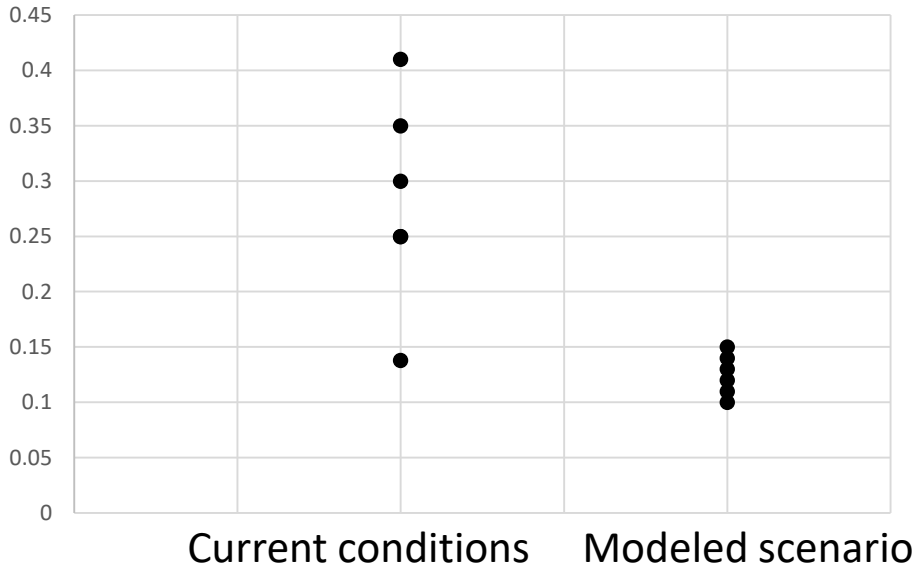
Increased proportion of run captured at weir



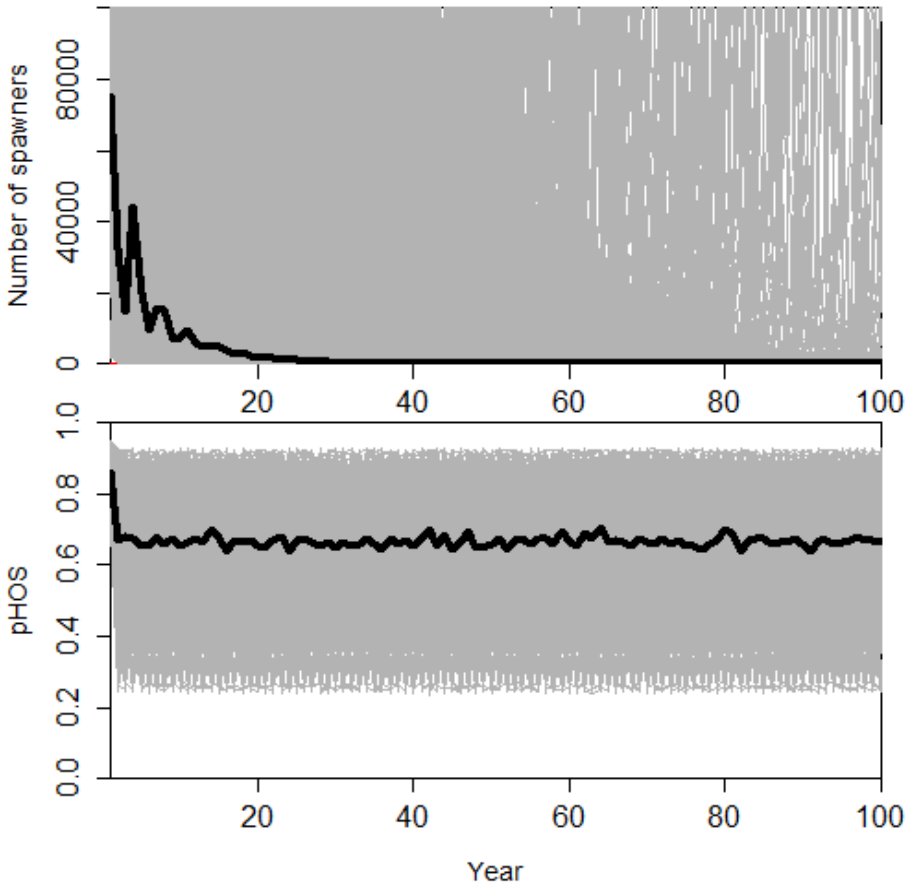
Current conditions



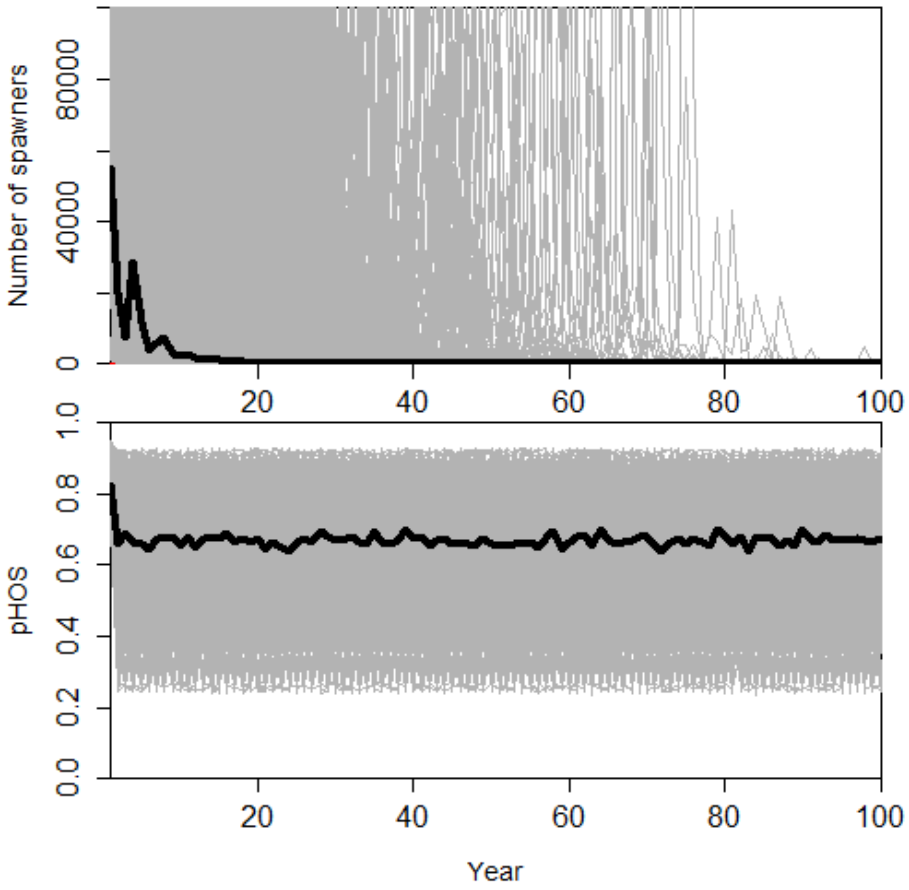
Scenario: decreased pre-spawning mortality



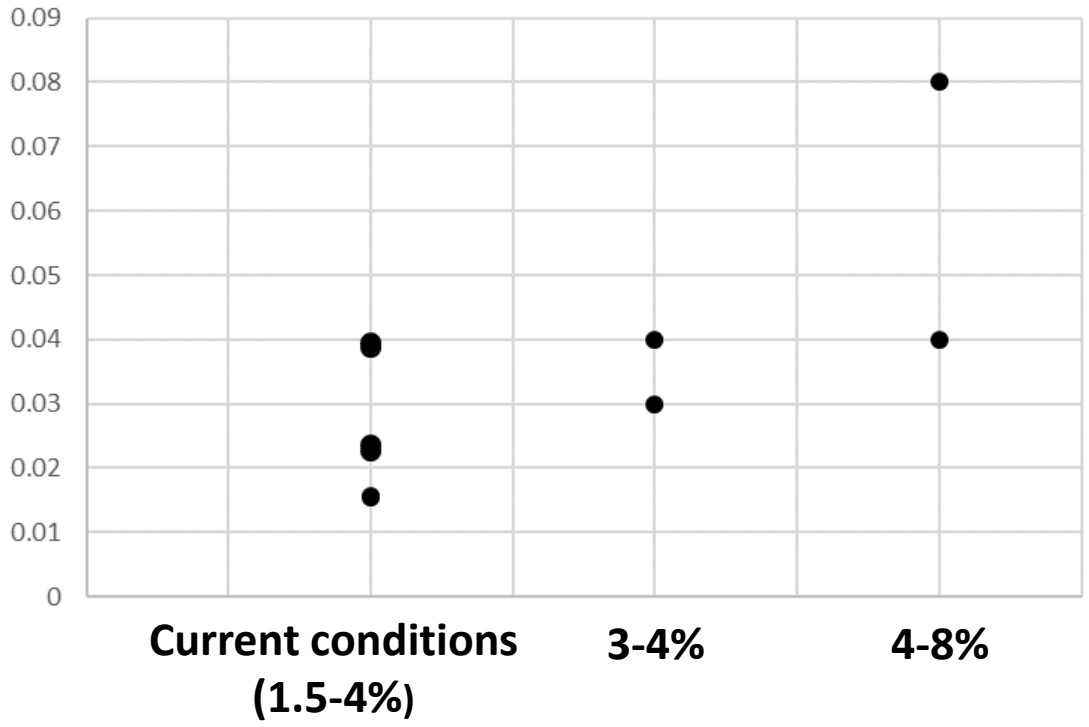
Decreased pre-spawning mortality



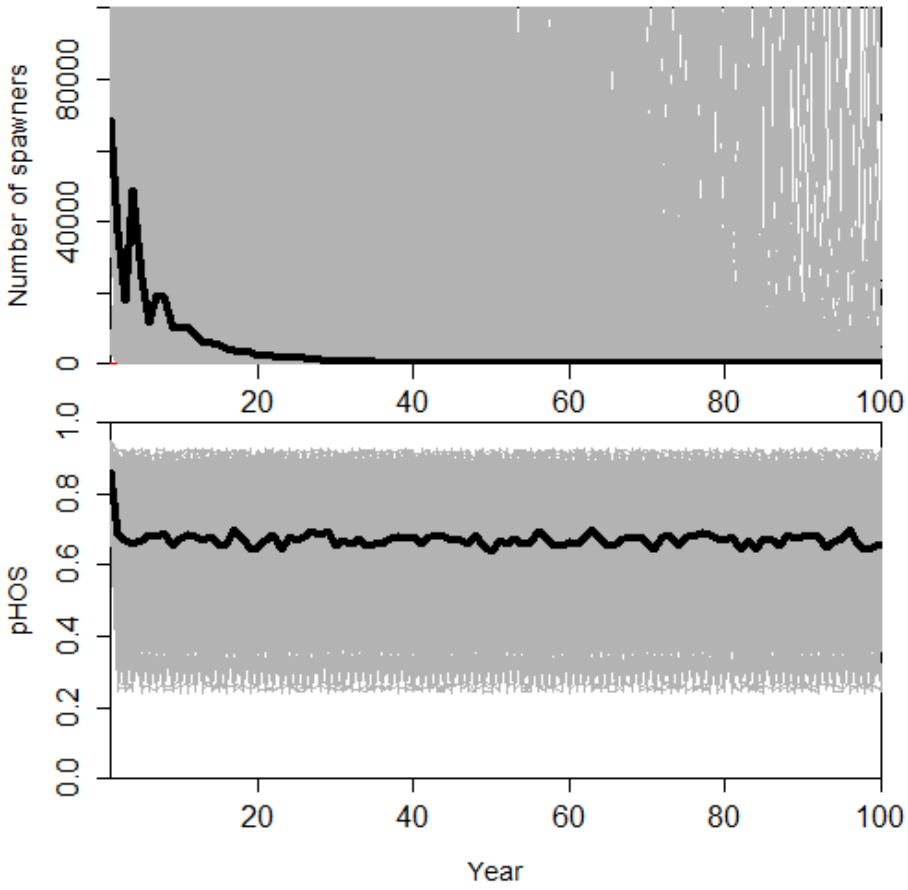
Current conditions



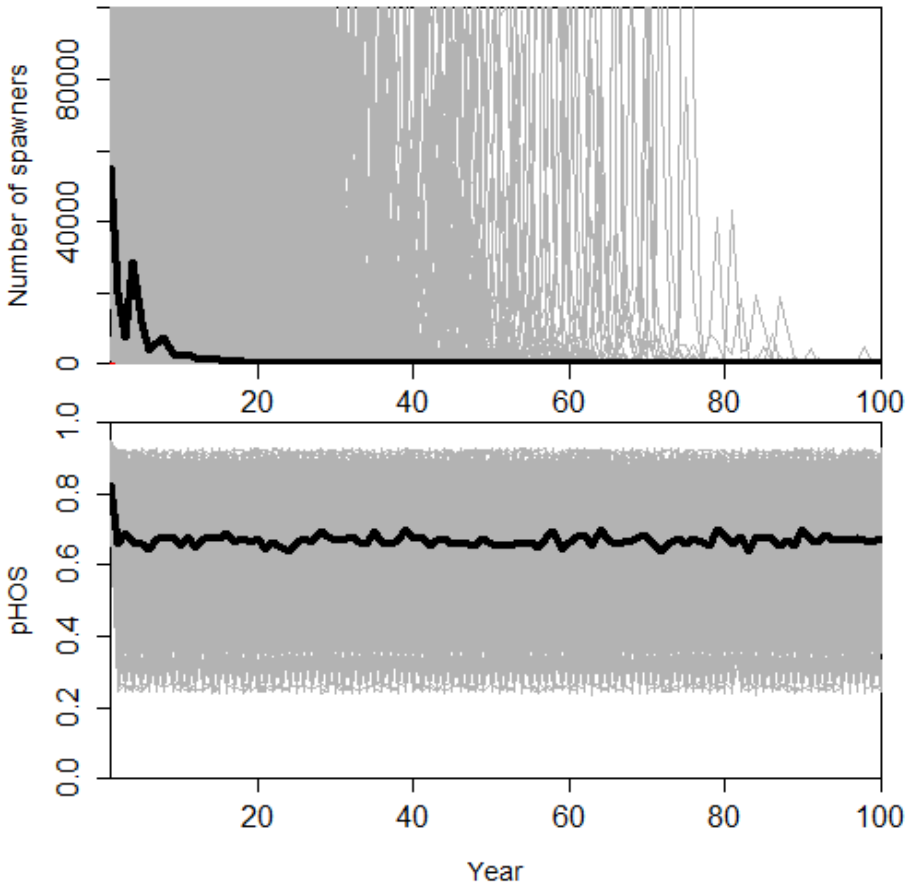
2 scenarios: increased fry-to-presmolt survival



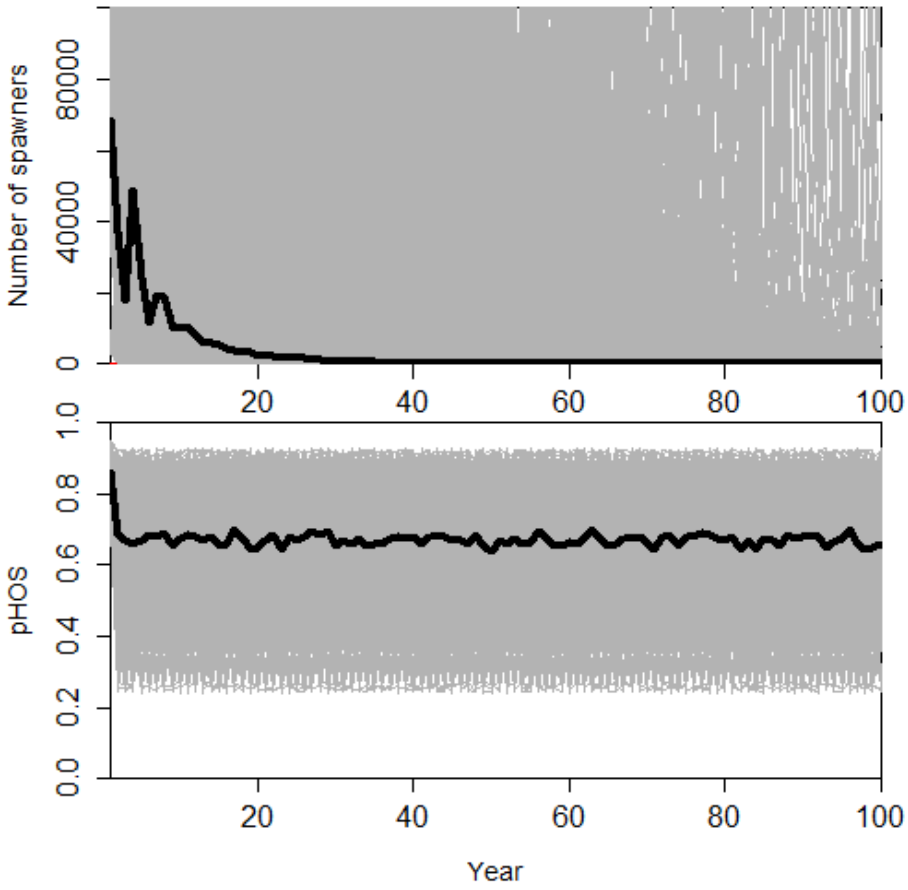
3-4% fry-to-presmolt survival



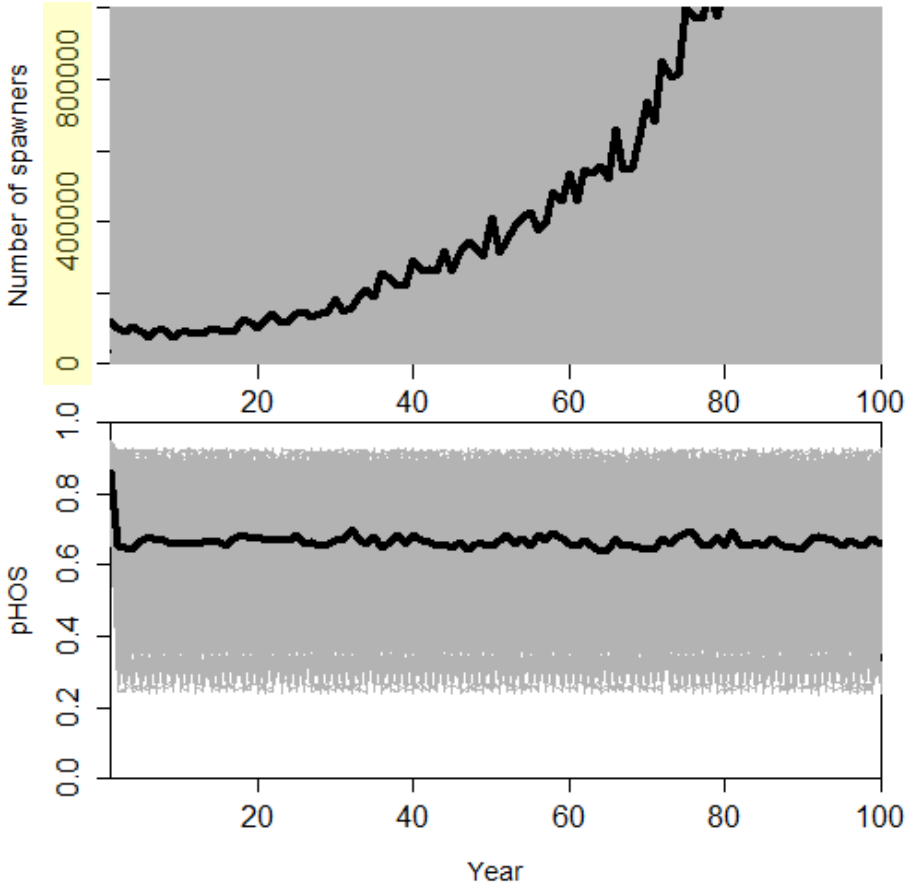
Current conditions (1.5-4%)



3-4% fry-to-presmolt survival

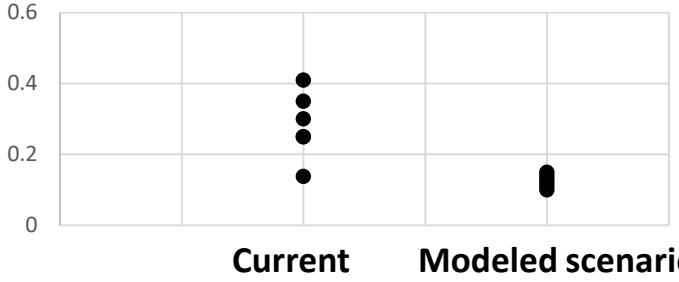


4-8% fry-to-presmolt survival

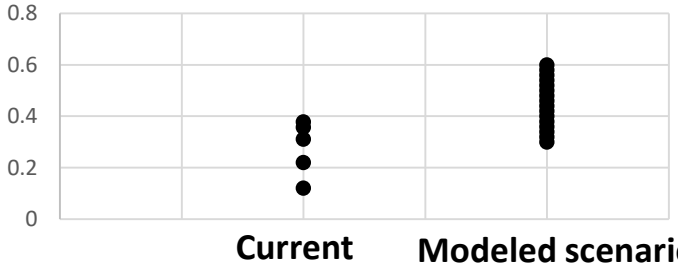


Scenario: 3 modifications

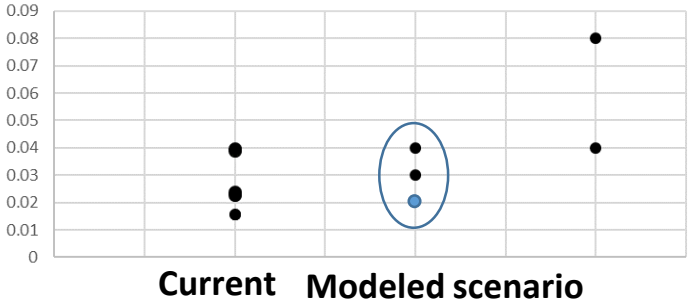
Decreased pre-spawning mortality

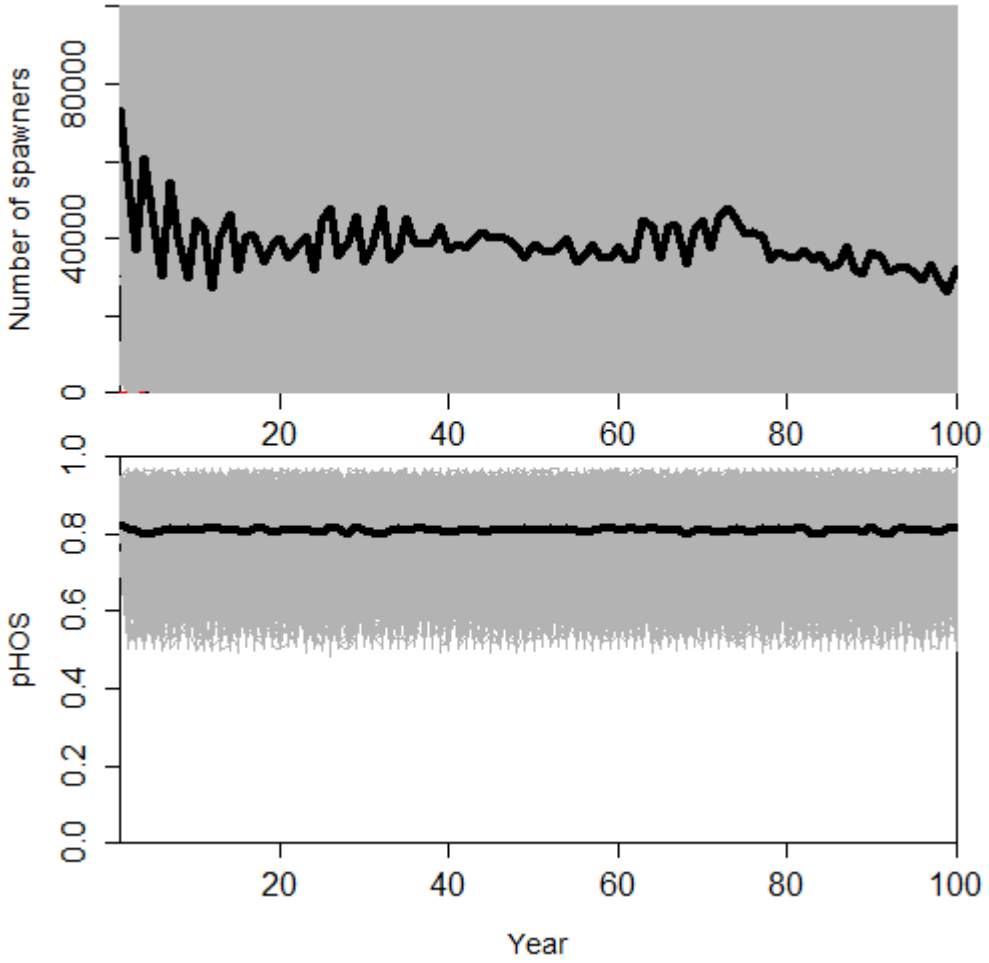


Increased proportion of run captured at weir



Increased fry-to-presmolt survival





Summary and conclusions

- Our analysis suggests that only small numbers of sockeye salmon will persist in Lake Washington under current conditions, much less provide future opportunities for tribal and recreational fisheries
- Maintaining the Cedar River sockeye run and restoring fisheries will be very challenging but not impossible
- The restoration of clear, clean, and swimmable water to Lake Washington in 1960s shows what can be accomplished with an engaged and supportive public

Data sources ("current conditions")

spawning BY	% female	Fecundity	Nat.EggToFrySurv	Hatch.EggToFrySurv	FryTo(pre)SmoltSurv	FryTo(pre)SmoltSurv--USE	SAR	SAR to locks	Prop. captured at weir	Pre-spawn mort	weir efficiency--USE	AgeComp
2000		3451	0.1526		0.038747226	0.038747226	0.0933	0.174512077	0.068970111	0.138		
2001		3568	0.1515	0.925	0.066946363		0.0243	0.032355381	0.060501281	0.138		
2002		3395	0.0853	0.88	0.022588899	0.022588899	0.2812	0.436727125	0.055117921	0.138		
2003		3412	0.2077	0.88	0.045751036		0.0018	0.002406854	0.053734694	0.138		
2004		3276	0.1968	0.914	0.023585572	0.023585572	0.0211	0.03140179	0.085188789	0.138		
2005	getting	3065	0.1422	0.877	0.01022044		0.0811	0.112741187	0.096403669	0.138		see
2006	data…	2910	0.0605	0.879					0.083154023	0.138		other
2007		3450	0.3225	0.87					0.04486826	0.138		Excel
2008		3135	0.0601	0.909					0.10413607	0.138		file
2009		3540	0.5658	0.909					0.188674174	0.138		
2010		3075	0.0491	0.9471	0.039415949	0.039415949	0.0206	0.047773003	0.106336171	0.138		
2011		3318	0.3762	0.926	0.039321748	0.039321748	0.0153	0.038279775	0.22049264	0.25	0.22049264	
2012		3515	0.3568	0.9374	0.015760143	0.015760143	0.0111	0.023583636	0.120245392	0.07	0.120245392	
2013		3362	0.1606	0.944	0.015488886	0.015488886			0.043344135	0.3		
2014		3368	0.7887	0.943	0.004350192				0.377626896	0.35	0.377626896	
2015		3070	0.196	0.936					0.310606475	0.41	0.310606475	
2016				0.94					0.356966391	0.25	0.356966391	
average	using 0.4 for now	3328	0.196	0.911		0.028		0.091		0.337	0.277	

Future alterations to consider:

- Need to refine % female data
- Need to refine fecundity data (fecundity by age rather than just an average value)
- Can break out fish by sex throughout the model
- Include small number of age 0 smolts
- Will consult with/get data from Heidy Barnett in order to quantify pre-spawn mortality from Ballard Locks to Cedar River vs. in-Cedar River pre-spawn mortality (and could separate natural vs. hatchery in-river pre-spawn mortality)

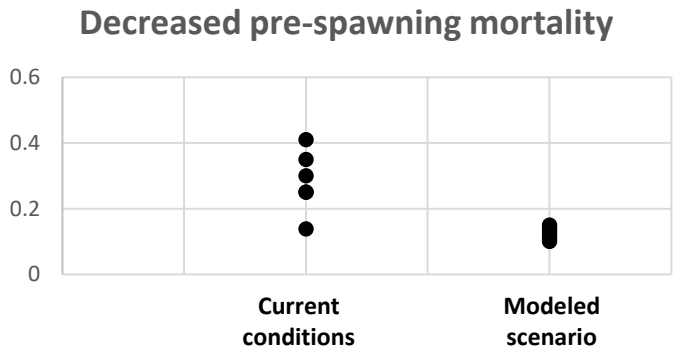
Data considerations:

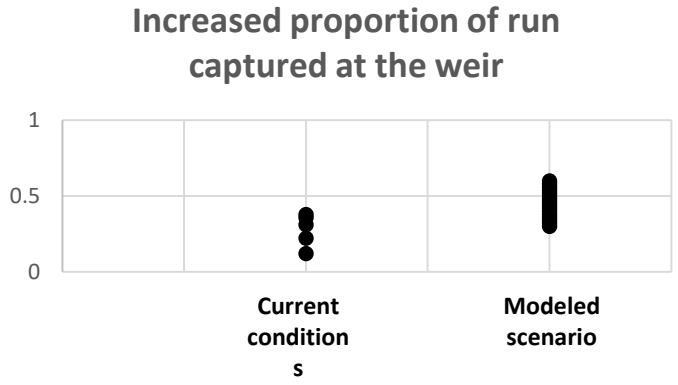
- Consider effects of the following on the results:

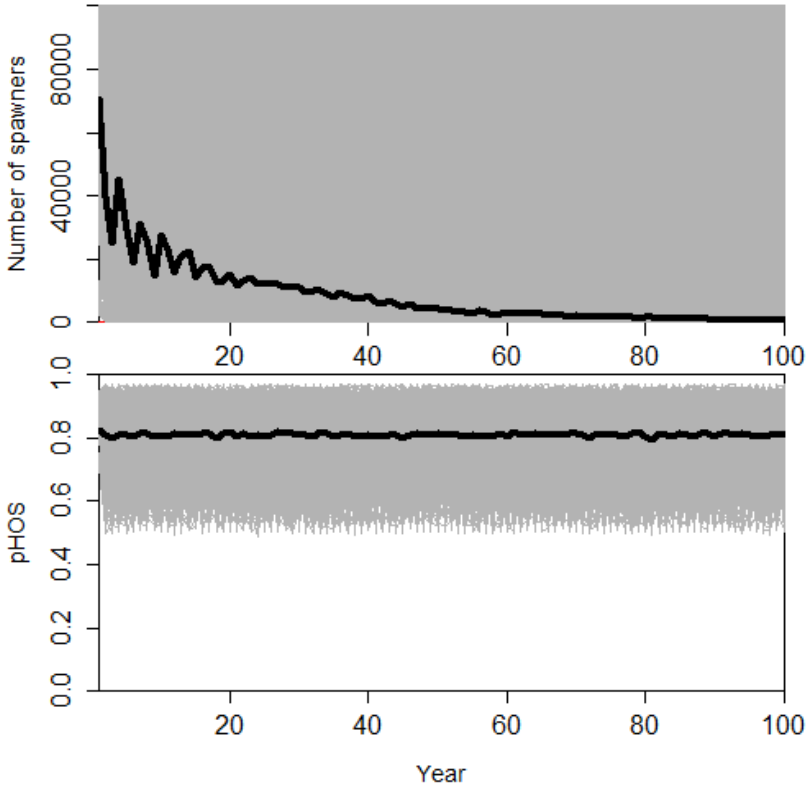
1. Underestimates of natural spawners, especially at low natural spawner abundance, which could lead to an overestimate of natural egg-to-fry survival
2. Fry trap capture efficiency issues—may result in inaccurate estimate of natural-origin fry
3. Survival of hatchery-origin fry from hatchery release to the lake is not quantified
4. Inaccurate estimates of pre-smolts in Lake WA (sampled in March before outmigration)
5. Because of underestimate of natural spawners, proportion of fish captured at the weir could be an underestimate

- Could model survival from fry to adults Ballard Locks to see if similar results are found (in order to double-check how much the individual survival/mortality rates within these stages are driving the results)

Scenario: decreased pre-spawning mortality, increased proportion of run captured at weir













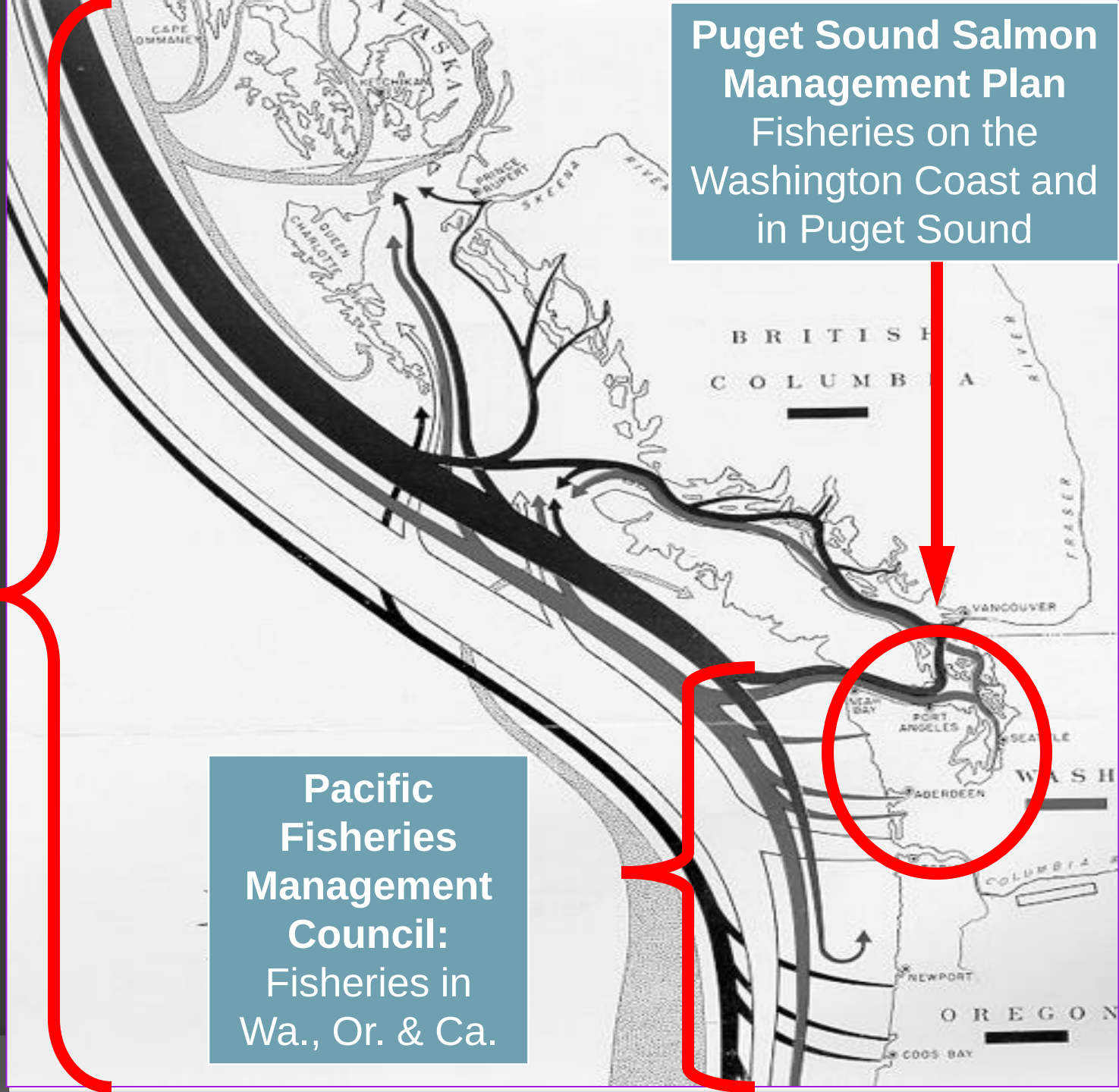

Chinook Harvest Management

Lake Washington Chinook

Pacific Salmon Treaty
Fisheries in Southeast Alaska, Canada, Wa., Or., & Idaho

Puget Sound Salmon Management Plan
Fisheries on the Washington Coast and in Puget Sound

Pacific Fisheries Management Council:
Fisheries in Wa., Or. & Ca.



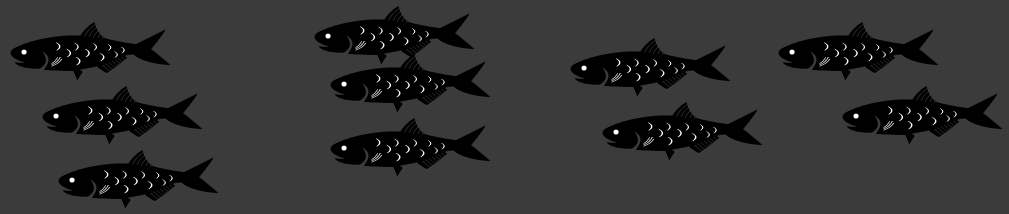
Management Criteria

Stock: Summer/Fall Chinook	Escapement LAT	ERC	ERC type	CERC	CERC type
Skagit - Total	4,800	50%	Total	15%	SUS
Upper Skagit	2,200				
Sauk	400				
Lower Skagit	900				
Stillaguamish	700	25%	Total	15%	SUS
North Fork Summer	500				
South Fork Fall	200				
Snohomish	2,800	21%	Total	15%	SUS
Skykomish	1,745				
Snoqualmie	521				
Lake Wa. (Cedar R.)	200	20%	SUS	10%	PT SUS
Green	1,800	15%	PT SUS	12%	PT SUS
Puyallup	500	50%	Total	12%	PT SUS
Nisqually	700	52%	Total	19%	SUS
Western Strait-Hoko	500	10%	SUS	6%	SUS
Elwha	1,000	10%	SUS	6%	SUS
Mid-Hood Canal tribs.	400	15%	PT SUS	12%	PT SUS
Skokomish	800	50%	Total	12%	PT SUS

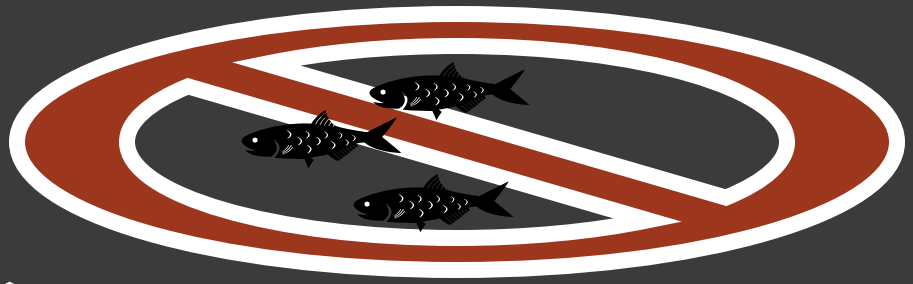
How is harvest controlled?

Exploitation Rates, example

10 fish

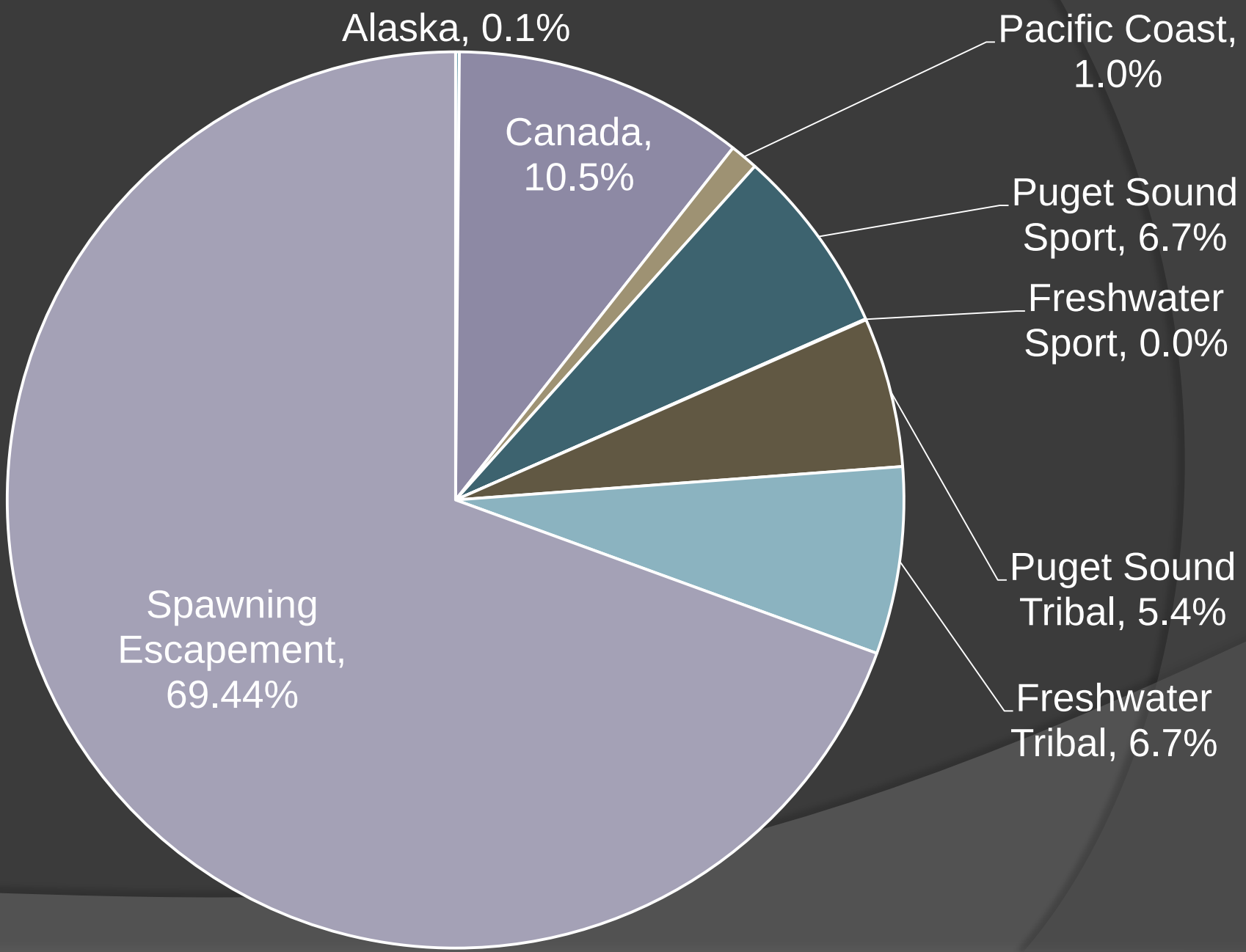


3 "harvested"



30% exploitation

Exploitation Rates for Cedar River Chinook



Cedar River Chinook Mortality